1 Introduction: Scientific Communities in the Developing World

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This book explores the constitution and growth of scientific communities and the status of scientific potential in the countries of the South. This subject, for a number of reasons, has received only marginal attention in the field of STS studies.[1] Despite the growing critical perspectives over modern S&T, it continues to occupy an instrumental role in the development agendas of developing countries which are relentlessly striving towards modernization and industrialization. The unprecedented wealth, standards of living, and comforts in transportation, recreation and communication made possible by the factors of S&T stand to inspire the ruling elites in the South. Much of the S&T potential in these countries, which we term as industrially developed, is constituted directly or indirectly by the efficient organization and functioning of their professionalized scientific and technical communities. Even though the real potential of S&T is enmeshed with socio-economic, political and other aspects, it is difficult to deny the centrality of the role played by S&T communities in the overall development process. Even a cursory look into the role of science in the South in relation to the North necessitates some degree of attention to the historical processes and to the relations established with the North.

During the last three centuries the countries of the South have recurrently confronted complex socio-economic, political, cultural and technical problems in the transposition, assimilation and integration of modern science, and in the realization of its potential for development. Colonial and post-colonial experiences in the countries of the South, as dealt in this volume, point towards different modes of challenges confronted by different countries at different historical moments. The fact that much of the S&T in the South came about as a part of the European colonial expansion for over three centuries, draws our attention to the complex ways in which colonialism structured and influenced the institution of modern science and the emergence of scientific communities.

The end of the Second World War and the disintegration of colonialism, which paved the way for national governments, witnessed massive efforts by many countries of the South to build national S&T institutions and relevant infrastructure in the post-War period. Even during the 'hey days' of colonialism, national or independent modes of scientific development had taken root in many countries in contrast to the then prevailing colonial mode of scientific development. For almost three decades or so after the War, this national mode of scientific development, which promoted the strategies of import-substitution and self-reliance in the overall economic policies, also governed the organization of science and the goal orientations of scientific communities.

Whilst the South struggled to translate the national economic policies within the S&T system, the period of the 1980s saw the countries of the South confront new challenges in their responses to new technologies such as micro-electronics, computers, telecommunications, new materials and biotechnologies. Eventually, this phase further imposed new challenges leading to the contemporary mode of economic restructuring and globalization. The historical growth of science as the most powerful tool and the role it played in the industrially advanced countries of the West raises many questions in the context of the South. Why is the worldwide spread of supposedly universalist modern science taking so long? Should we not recognize that there are several types of scientific knowledge or 'ethnosciences' (embedded in indigenous contexts and partial to favourite ways of reasoning and understanding the world), or several ways of practising scientific research rather than a single universalist mode, and different modes of their development which are conditioned historically? And, what are the obstacles or inhibiting factors for the evolution of modern science in the context of its historical rootings in the non-Western countries?

This volume brings to bear different social perspectives current in science studies on the understanding of science and the growth of scientific communities in the countries of the South. Even though the focus and the perspectives adopted by various contributing scholars vary in many respects, there is an underlying recognition of certain social and historical processes influencing the growth of science in the countries of the South. Further, the consideration of S&T as a social activity in the larger context of societal development forces us to recognize a variety of exogenous and endogenous features. S&T influences society as much as society influences the stage or status of science. Thus, there is as much reason to consider the role of exogenous actors and agencies as the endogenous domains of science in a particular society. From such a standpoint, some important questions which come into focus are: Where and how does science find its support and legitimation? Who are the key actors? What role does the ruling political system play? In what ways does state mediation influence educational and S&T structures? Do external factors have a bearing on the content and direction of scientific fields? In what ways do the leading and elite science groups and individuals appropriate the limited S&T resources and how do the others get deprived? What role does the international connectivity of science play in the national or local context of science? And, why is it that despite sometimes comparable outlays in science amongst countries the results are skewed and vary dramatically?

The country case-studies in this volume throw ample light on many of these issues to enable us to draw a comparative picture. As the focus is laid on the empirical insights into the emergence and effectiveness of scientific communities in the countries of the South, we need to have some common understanding of the institutional features which are important as shaping grounds. The first section of the introduction deals with this aspect. The subsequent section of the introduction then explores colonial and post-colonial experiences for the emergence and growth of scientific communities in the South. Having dealt with the post-War optimism about science for development, some attention is laid on the contemporary crises and challenges facing the South.

Shaping Grounds: Perceptions of Learning and Political Legitimacy

In this section we deal with three conceptual issues, namely, perceptions of learning and legitimacy, styles of science and socio-cognitive structures, and scientific communities and professionalization, which are seen as critical features in the institutional growth of modern science.

Scientific activities in the South seem to find their sense of meaning in stages and one-by-one in societies where perceptions of learning and legitimization may come from different world-views. In the South, the status of modern S&T in orienting social institutions greatly depends on the political legitimacy it draws and enjoys, particularly in the early stages of institutionalization. There are of course various social interests, established natural philosophies and social orders of learning with which the institution of modern science competes for its legitimacy at the social and political levels. We will illustrate one example from the work of the ethnologist Hagenbucher-Sacripanti (1992) on the therapeutic routes espoused by the sufferers of AIDS to deal with it in Africa. This will help us understand the resistance of fields of learning to the early grounding of modern science in the African context.

The Vili and Yombe Tribes of the Congo, in common with the rest of the Bantu world, believe that the universe opens itself up to human understanding through a dual organization—the diurnal world and the surreal world—peopled with the souls of the dead, the doubles of the living (capable of dissociation) and their monstrous helpers. This dichotomy is mirrored in the human being. The causalities of disease are interpreted in line with such metaphysics coupled with cosmology. Spiritual entities (*nkulu*) or natural powers (*nkisi*) operate in the surreal world, wherein the local experts are working according to strict rules in order to make contact with the 'demons' taking over the 'doubles' and trying to control or dispel them. This structured system of symbolic representation, which legitimizes groups of specialists and traditional powers, is in variance and incongruent with the views and methods upheld by bio-medicine.

The point is that the modern systems of knowledge, to find credibility among the traditional societies, have to operate by making use of the local discourse, though the methods used may be quite different. The traditional patterns of explaining illness, as well as other forms of local knowledge systems, are rooted in traditions and pose considerable resistance to change in favour of modern rational reasoning. Often, bio-medical practices here have to work in the midst of such traditional practices and even express themselves in their terms in order to find acceptance. Joseph Needham (1956) in his monumental work notes the conflicting effects of the Mandarin spirit and the Taoist mystic in ancient China; the former, which is dominant, discards the very idea of natural laws and considers only the knowledge dealing with putting the human world in order as possible and worthy; the latter, on the contrary, is interested in the observation of Nature and its regularities, and has inspired many inventors (frequently craftsmen and lower class people). One can draw many examples in the Indian case, wherein the traditional system of caste-based hierarchical occupational structures posed tremendous resistance to the perceptions of modern learning and the internalization of the rational spirit (see Weber, 1951, 1958; Ray, 1918; and Ray, 1958). Early nineteenth century social reformers in India, such as Raja Rammohan Roy, relentlessly struggled both on the political and cultural fronts to mobilize public opinion in favour of modern learning against the traditional, Sanskrit-based learning.

The fact that science needs to establish and assert its intellectual authority in the context of traditional perceptions of knowledge calls for the greater need for political support. The creation of modern educational structures with all intellectual and material infrastructure while taking into account the diverse socio-cultural and socio-economic stratifications in the countries of the South underlines the importance of political support and legitimacy. Modern science was to build on this from the end of the nineteenth century within the framework of European imperialist expansion—albeit worryingly—known to pride itself on its powers through military as well as civilian trade modes. Beyond the constructive contribution of the colonial powers, which was however extended only in a limited form, the efforts of the national governments in the post-War era are also considerable. So far, however, scientific and technological systems in the South (with some exceptions) have not been able to permeate the socio-economic structures as we see in the North. There, techno-sciences have become productive forces and their assimilation in society has been achieved through various processes of legitimization for S&T systems. There is no similar situation in the countries of the South. On the contrary, the resistance coming from the traditional and indigenous systems of knowledge and learning, including the corresponding agencies and actors, entailed tremendous political support for the institutionalization of S&T institutions and education.

Thus, the role of liberal, rational and modernist forces has been an important determinant in the growth of modern science. From the late nineteenth century, the local intelligentsia gave tremendous importance to modernization and industrialization. Very often, these forces had to develop strategies and alliances with the ruling political and military regimes. The context and the purpose (military, industrial and socio-political goals) which helped science to acquire the needed legitimacy varied in quite a contrasting manner in the countries of the South. It may, however, be pointed out that the feature of science acquiring legitimacy did not take place as a result of intellectual or endogenous processes. The political inducement in assigning the legitimacy, as historical experience demonstrates, led to many positive as well as negative or dysfunctional results in the overall assimilation and integration of science in the South.

Thailand owes the voluntarist introduction of its initial scientific activities to princely ruling elites led by King Chulalongkorn. Promotion of science was a part of the political framework to modernize Thai society as well as guard the country against foreign imperialist hegemony. The role of the nationalist forces in science in India and the part played by Nehruvian elites are other examples of positive elements. The privilege granted to science by political regimes can also be seen to be rooted in a secret affinity with the way political powers view their own foundation in society. Thus, a Venezuelan dictature lavished its support on both neurosurgical studies and nuclear physics, joined in one single brand-new institute: a strange gathering, not unconnected with the image of disciplines striving to fathom the most intimate secrets of man in the world—those which the regime intended to master. Open democratic set-ups with a transparent decision making process have greater chances of making positive contributions as the space for constructive dissent is built into the system in one form or another. But the problem arises in some of the dictatorial and military driven regimes. As the redundancy of myth proves its implicit cosmology, scientific achievements underscore here the claim to legitimacy of that power, by highlighting its transposed image.

By giving much needed political legitimacy, political regimes also promote a steering ground of science to the scope the governments consider they are entitled to choose in the name of 'public good'. When the regime changes, there is a swing in the policies which has a bearing on the institutionalized areas of research. There are some examples of negative consequences. Persecution of scientists during the Cultural Revolution; mishaps suffered by the fledgeling Argentinean scientists; and the repression of Brazilian academics by the military regime in the 1960s are some instances. On the other hand, there are instances at different historical moments in the countries of Brazil and Algeria wherein the military regimes have played positive roles. We also have examples from countries such as South Korea and Taiwan, wherein the S&T systems drew considerable political support and legitimacy from the respective ruling regimes. There is enough empirical evidence in the case of South Korea to show that the fields of science have immensely gained from political support in forging valuable linkages with the production system. Some of these examples raise the question of the types of political legitimacy accorded to science. Historical experience shows that whilst political legitimacy is an important factor for the initial growth of the institutions of science, the system of science needs to command a certain degree of research autonomy from the direct interference of political or ruling elites.

If political legitimacy is one of the most important factors for modern science, it is all the more so when the intellectual field is already well structured with little space for new approaches, or when the enterprises at stake become more capital intensive, as they tend to be in 'technosciences'. However, no less important are the socio-economic and cultural features. But here too, political connectivity and mediation are crucial, as the governments in the countries of the South in the post-War period sought to incorporate these features in their political agenda of modernization and industrialization. Varying sources and forms of legitimacy for science in the South have led to corresponding mainstream institutional bases and loci. Government agencies as in the case of India; the military regimes and relevant industrial complexes as in the case of Brazil and China; university settings as in the case of some Latin American countries; and the state-mediated private industrial complexes as in the case of South Korea are some of the examples of the connection between the feature of legitimacy and the constitution of the main institutional locus for science. However, apart from these developments which have come about in the post-War period, there are other agencies and sources of legitimacy which have led to other institutional loci in the countries of the South. The Chinese Academy of Sciences and the Public Sector Enterprises in India are such examples. Varying institutional contexts of loci and support draw our attention to the feature of different styles of science and socio-cognitive structures in the constitution and growth of modern science in the countries of the South.

In any case, no one should think that the budget and the state are the creators of science. Other forces are at work, generally earlier in the process, which encourage scientific vocations and create long-lasting support among various social groups. We propose here several concepts to deal with these initial, or non-state run, stages. *Styles of science* flow from the local appropriation of methods of reasoning, each focusing attention on certain phenomena, principles of explanation, and fields of action. Such appropriation processes owe much to the ethics and personalities of the pioneers who interpret the local context through their own world-views and life experiences (cf. the Algerian case study later in the volume). Small groups of followers, forming the first *scientific communities* (initially personal acquaintances), become accustomed to those styles. Later on, when formal research training gets organized and scientific activities differentiate themselves, *models of professionalization* spread by leading higher education establishments tend to replace the less formal scientific styles. At a macro-social level, the contest between models of professionalization (or scientific styles) may echo the competition of social factions and their conflicting projects. Science may thus make common cause with one of them (e.g., again the Algerian case), or two different *socio-cognitive blocs* may continuously confront each other concerning the type of science that should be developed (see the Venezuelan case in this volume), until one is eventually triumphant. Finally, the impetus to the development of styles of science and their spread through the world owes much to the state of international affairs, especially to the execution of imperial plans, hegemonic projects and counter-hegemonic responses. Long-lasting regimes or *modes of development of science* (colonial, nationalist, etc.) shape the scientific field throughout the world. We shall now discuss some aspects of these forces which are of special importance in the countries of the South.

Styles of Science and Socio-cognitive Structures

Even though the universality of science is hardly debatable in terms of scientific laws, equations and results, the preferred ways of reasoning, the sorts of problems identified, and the practice and social processes of scientific research cannot be taken for granted in universalist terms. We have noted earlier that scientific styles, which are the trajectories of scientific discoveries, owe much to the personality of pioneers. We must add that several styles often coexist and compete in the same scientific field. Following Nathan Reingold (1991), it is pertinent to conceptualize different national styles of science in the context of Southern countries. The organization and administration of mainstream science, publication practices at the country level, the locus of science in the university or non-university settings, and the national strategies which govern the goal direction of the scientific community at the national level, all subscribe to the understanding of national styles of science at the macro level.

Basically, style of science signifies the broad organizational culture and the goals governing the orientations of a scientific community, and ways of reasoning and approaching the world. These are elaborated in markedly social, political and ethical cliques under the direction of certain leading lights and charismatic leaders, and implemented within a choice of disciplines and science related socio-economic or even politically significant fields of activity. On exploration they later exhibit something in common (beyond scientific content) with the visions of the world and life experiences, not only of key scientific figures and their followers but also of social groups or types of regimes interested in supporting them. We notice that such styles are resistant for a period of time insofar as they take on meaning through mutual contrast—as the social groups supporting them do—developing with them socio-cognitive blocks which can take part in public debate. Those are later replenished when new groups or regimes take on the reins. At the historical level of understanding, the composition of different opposing or contrasting styles and socio-cognitive blocks within each country are discernible. There is the case of the 1930s' split in Venezuela between academic and development science. In India, the period after the turn of the present century reflects the nationalist style of science in contradistinction to colonial science.

Similarly, one can explore this feature at the meso level of different science agencies such as space, defence, atomic energy or civilian industrial research, medicine and health. The notion of contrasting styles of science at the meso level is often constituted by different kinds of scientific personalities or leading scientific elites. Each is oriented by social ideals and moulded by an understanding of what science is and which science is worthy. Each is attached to a cognitive strategy. It is embodied in people or flagship institutions. It determines the penchant for particular disciplines, the preference for a school of thought, the very choice of research subjects. This then produces the professional norms and practices to be prized—cooperation or solitary work, good external relations or entrenchment, cosmopolitanism or autocentricity—modes of publication, and taste or contempt for theory or application. The scientific field is structured by these styles of science (and their local hierarchies), ensuring newcomers fall in line with institutionalized practices. The styles themselves operate as real modes of production. They are the vectors of selective approaches to the world and discoveries. It is important to identify them, and not just because they serve to guide the heuristic procedures. The key appears to be the fact that their confrontation provides the basis upon which socio-cognitive blocks or structures are formed, exposing what can be expected in terms of social support.

Scientific Communities and Professionalization

The concept of scientific communities or specialist groups has been in vogue in STS literature for quite some time now. Sociological studies from Mertonian, Kuhnian and neo-Kuhnian perspectives have drawn our attention to critically examine the normative, interpretive and social constructivist aspects of science. Here, we need to go beyond and conceptualize the term 'scientific communities' at the broader, national and local contexts of developing countries. We wish to stress three features with regard to the understanding of 'national' scientific communities. First, following Thomas Schott (1991: 442), this term is conceptualized as follows:

> The scientists within a country form a national scientific community, a community within the world scientific community. They enter the national scientific community through the relatively similar scientific education which they have undergone and their acquisition of the shared culture of science—at an elementary level. They perform their research in the framework of national institutional arrangements for research such as universities with similar patterns, the same national associations and journals, supported by the same national foundations and the same bodies which set the national science policies; thus, they perform their research within a common institutional and intellectual setting. All this prepares them for participation in the more differentiated and specialised traditions of scientific knowledge and research, and for personal connections which are more intense with colleagues who are nearby working on similar subjects and problems, and also with more remote colleagues.

The concept of national scientific communities also signifies the formation of national identities (that is, a place in the international sphere of science) in the practice, production and advancement of scientific knowledge. The formation of national identities is, however, a historical process (long to achieve and now questioned by the new internationalization of science). Some country case-studies have touched upon this feature in this volume. There are large size communities in countries such as India and China; medium size communities in countries such as Brazil and Egypt; and small size communities in countries like Senegal and others. The size in terms of numbers does not signify the existence of local, national communities. The basic indicator is a steady production over years in special fields or sub-fields of science. The constitution of local, national disciplines, creation of university chairs, systems of national recognition and rewards, higher specialized educational structures for creating neophytes, full-time specialized research structures, and areas and networks of scientific research and communication with corresponding professional societies and journals signify the existence of local, national communities. These are constituted in terms of groups of differing sizes and configurations and to a large extent on the basis of larger scientific disciplines. These disciplinary-based communities can be seen to function as 'kinship' groups. The notion of a tree-like model with branches, etc., fits into the description of scientific communities based on disciplines. New branches are like new emerging areas or sub-disciplines. These notions hardly need elaboration and have been well described, though in somewhat different terms, by Whitley (1975, 1976 and 1978) and others. Like the family tree, the scientific community model can accommodate the creation of new segments and genealogical alterations. It serves as a support for strategies, shifting the emphasis of an event (a discovery, a conflict, the opening up of a new field), and modifying its terrain and scope to the level to which it can be proved to belong. It may be noted that there are larger discipline-specific communities as biology and chemistry; speciality-based communities as biochemistry or molecular biology; and communities of inter- or multi-disciplinary fields such as health, urban planning or architecture. The growth of the tree-like model also signifies the professionalization of a particular discipline. Even though the autonomous growth of disciplines and specialist communities cannot be ruled out in the South, the question as to why certain specialist communities emerge and why others do not in a particular country context is related to the 'charisma' of pioneers, their networking ability, national support obtained and strategies adopted.

Second, from the sphere of the world scientific community, the national scientific communities in the South may be said to constitute a 'periphery' in terms of the funding they are granted and the extent to which they contribute to the advancement of knowledge. Only a small proportion of the community in the South is part of the world effort in science. In other words, the major proportion of scientific communities in the South is governed and influenced by their national socio-economic goals. There indeed appears to exist some form of neo-colonial legacy, in the sense that the cutting edge of the *research frontier* is dominated by the metropolitan centres of the North, whilst the South continues to work on what may be called the *research back*. Often one can notice a serious legitimation crisis in the goal direction of science between the local and national demands, and the *hot* areas of research in vogue in the world sphere of science. Few countries are aware of the serious issues entailed by this division of labour in world scientific research. The scientific advance of the North has now become a potential weapon, threatening the traditional production and employment in the countries of the South (Busch, 1996). The latter should necessarily make efforts to promote on their territories the growth and professionalization of scientific communities, and to strategically track the research frontiers in the North. This affords an important *window* for the inflow of new ideas and techniques.

Third, much of the effort in the countries of the South is now directed towards making their national scientific communities more viable and effective by developing the institutional linkages between research, industry and market locales. More than anything else, many countries of the South are still striving to strengthen their national scientific community structures, which basically refers to infusing excellence and relevance in the higher educational and training structures, particularly in the new areas of research such as biotechnology; constituting professional societies and journals; reforming the peer review systems, both in the funding of projects and productivity patterns; and strengthening the network of interactive communication channels. Many of these features have to do with the process of professionalization which is to be distinguished from the institutionalization of science and the nascent birth of scientific communities.

A highly professionalized scientific group in a discipline not only constitutes a community at the national level, with some degree of international standing through its contribution to the advancement of knowledge, but also one which commands a certain potentiality to forge viable linkages with the production-oriented segments of the economy. The transition from communities to professionalized groups entails some routinization of activities and defined moulds of training. Widely recognized ideals and professional norms replace references to the local code of ethics and system of values. Exemplary laboratories, rather than personality based figureheads, become the rallying banners. The charisma of exceptional personalities in science does persist at a symbolic level but gives way to bureaucratic and intellectual leadership. Cognitive structures are steered by an ideal of the *quality product*. It becomes possible to organize the cooperation of scattered pockets of researchers involved in the same work for a collective programme or product. The transition towards the mode of professionalization necessitates a link-up with outside interests, the seizure of opportunities, the building of a social demand and the formation of a sustainable system to reproduce that demand. This is why an increasing trend in the constitution of inter- or multi-disciplinary communities of specialists can be taken as a good indicator of growing professionalization. Another indicator, among indicators of a community of science being professional, is the degree to which this community in a particular area of research not only checks the potential brain outflow or brain drain but in various ways attracts native talents or even brains who emigrate for purely professional reasons. There are indeed different 'modes' of professionalization in related ares of S&T. The training system is important here, as it not only ensures the acquisition of knowledge and operating procedures, but also inculcates ways of reasoning and bents of action. There are typical cases, as the case of Singapore, explored in a study by Goudineau (1990). This study demonstrates the mode of technical professionalization engineered by private industrial demands and government mediation.

Singapore's experience has some kind of parallel with that of South Korea and Taiwan, which in various ways emulated the Japanese post-War experience. The experience in the 'Dragon' countries shows that these countries created scientific potentials even before establishing scientific communities and science did not take the form of a 'vocation'. The incentives were basically economic and the norms and patterns of behaviour in the

S&T related institutions reflected a form of professionalism. Scientific potential was not developed within the framework of an autonomous scientific field and the social system of science but within the framework of state-mediated science–industry complexes. The scope of these experiences cannot however be generalized to other country contexts, but they are examples of technical professionalization modes which are 'unique'. We have taken into account the South-east Asian experience to bring into the discussion different modes of professionalization relatively in variance to the one induced from the concept of scientific communities, and obviously linked to new 'modes of scientific development' discussed later.

This does not however suggest the residual or minor importance of the concept of scientific communities in the South. The importance of developing scientific communities and promoting their professionalization will assume greater importance in the future, especially in the areas of agriculture and the biological sciences. It is unlikely that the traditional and conventional forms of technology transfer will take place from the North to the South in these areas and fields. Given the integration of research, industry and trading organizations in the North, and the emerging international regimes in Intellectual Property Rights, it will become necessary for the South to develop scientific potential in some of these crucial areas of research, such as agriculture and the biological sciences, locally. Further, the need to forge close linkages between research, industry and market locales in the South demands networking of scientific communities with contractual partnerships with these segments of the national economy. These developments, which have already taken shape in some countries of the South, signify a newer conceptualization of scientific communities. One may even speak of hybrid communities.

So far we have been exploring some general features underlying the concept of scientific communities from a sociological angle. We will now turn to the historical dimension. The impact of colonization, the efforts of the independent nation states in the South for promoting science and the way in which the South experienced stages of optimism and disenchantment will be explored in the later sections.

Modes of Scientific Development: Colonial, National and Private

The notion of *mode of scientific development* brings some of the relations science has with its environment into the analysis, particularly what the perceptions of learning are (what knowledge is of value and which science does the society need and why), the relationship with politics, and the links between the scientific field and other social spheres (which assign a place to science). Some configurations are stable for relatively long periods of history. Once transposed, the notion of a mode of scientific development is equivalent to that of a *regime* in history or a mode of regulation in economics. A mode of scientific development favours or disqualifies certain areas of research, privileges or smothers certain styles of science, promotes or hampers professionalization, and imposes views of the world which can facilitate or hinder certain avenues of research or paradigms. Modes of scientific development are no easier to stamp out than technical paradigms of production. They can be outmoded, repressed, yet they never completely fade away but settle instead like sediment to the bed of a hierarchical structure. The following section is devoted to what we see to be an important mode: the colonial mode of scientific development, that is, a system of scientific practice organized in the European empires from the nineteenth century.

The Colonial Mode of Scientific Development

During the last fifteen years, particularly the last decade, the sub-discipline of the history of S&T has generated a fairly large new corpus of knowledge which demonstrates the intimate connections between science, technology and colonialism. Domination and expansion of British, French, Spanish and Dutch colonial empires in the greater part of the globe between the seventeenth and mid-twentieth centuries was engineered through the power unleashed by the instruments of scientific and technical systems. Commerce, the flag, and the use of systematic knowledge about the nature and techniques of production and communication formed a symbiotic relationship in each of the colonial empires in their expansion to acquire colonies in Asia, Africa and Latin America. In some cases, the flag followed commerce, and in other cases commerce followed the flag. But in both cases, the power and use of scientific and technical means made possible the penetration of European colonialism. There is enough evidence to suggest that the first encounter of these societies with modern S&T came about as a result of European colonization. However, explaining the cultural transmission of modern S&T solely through political and commercial means would be a dominant, but one-sided, picture. The role of missionaries, the individual curiosities of metropolitan naturalists and later scientists to explore the new world, and the efforts of political and non-political elites in the colonies to draw on the 'stocks' of European scientific revolutions from the eighteenth century also played a significant part in the transmission of modern science to non-European culture regions.

Despite the burgeoning field of science, technology and colonization, the sociological understanding of the emergence of scientific communities in the developing countries (most of which experienced the waves of European colonialism) some how glossed the historiographical terrain of this field. Among the questions discussed, some are worth considering. Did the process of institutionalization of modern science in the colonies also lead to the process of professionalization of the scientific and technical fields? What is the connection between colonial science and the emergence of scientific communities? What was the contribution of European scientists transpositioned into colonial settings in the development of local, professional identities? And, what bearings did the colonial scientific enterprises have on the development of local scientific communities? Various chapters in this volume throw ample light on these questions. In this section we will take up only some crucial features of colonialism and science at a general level. To some extent this also relates to the non-colonial context such as Thailand and China, on the one hand, and the present contrast between Latin America and Africa, on the other hand.

CONTENT AND GOAL ORIENTATION OF COLONIAL SCIENCE: Following Basalla's (1967) paper, the concept of colonial science gained tremendous currency and at the same time generated considerable debate in the last decade. As the chapter on India in this volume shows, the colonial mode of science exemplifies an unequal relationship in scientific and technical pursuits between the metropolis and periphery. The Indian case is however not specific. Much of the content of scientific pursuits in the colonies of Africa, Asia and Latin America was confined or bounded to exploration, surveying, data gathering, and application of techniques to aid and promote colonial economic policies. The main goal of resorting to modern science and technological systems in the colonies was profit, and in some cases to aid colonial expansion.

There are many examples of individual explorations of the flora and fauna of the colonies, but the exclusive nature of such curiosity is uncommon and was often unthinkable considering the cost and dangers of such expeditions. James Cook's voyages to the Southern Hemisphere (Australia) were marked with scientific achievements such as astronomical observations of the transit of Venus, but these voyages also led to the claiming of the Southern continent by the British Crown. Similarly, Joseph Banks' voyages and botanical activities were 'important in establishing—the potential for new British settlements—and a penal colony in New South Wales. Subsequent expeditions to the area claimed more land for Britain, including Tasmania, New Zealand, and as many of the Pacific Islands as possible' (Browne, 1992: 464). The Beagle Voyage under the leadership of Robert FitzRoy to the South of America was also significant from the commercial and political angle, as the Argentine states opened up from their commercial trade pacts with Portugal and Spain. The duty of FitzRoy also included reclaiming the Falkland Islands from Argentina (ibid.). In the case of France, the detailed study of McClellan II (1992) on French Saint Domingue in the eighteenth century demonstrates the vicissitudes of French colonial science, both for profit and for political domination. Significantly, relating to the content of French colonial science, McClellan II (ibid.: 293, 295) concludes that 'not only are the higher reaches of the more difficult mathematical sciences scarcely to be found, but the theoretical dimensions of any of the sciences—exact or otherwise—are not part of the story of science in colonial Saint Domingue . . . . Colonial Saint Domingue needs to be seen as part of 18th century France'.

In nineteenth century France, the founding of the Société Zoologique d'Acclimatation in 1854 and its experimental zoo in Paris, the Jardin Zoologique d'Acclimatation, during the Second Empire with a membership of over 5,000, played a significant role in the extension of acclimatization theories for practical purposes of physiological adaptation and as a heartening ideology in aid of colonial settlers in North Africa, in particular Algeria (Osborne, 1992). From a different perspective, but not unrelated to the issue of the content and goal of colonial science, Chambers (1987) poses the problematique of the *Enlightenment* for the history of colonial science in eighteenth century Mexico and Latin America. Implicitly or explicitly there existed a division designed by the colonial powers between the centre and periphery—the latter serving as a form of data field for the theoretical synthesis in the metropolis (see also MacLeod, 1982; Inkster, 1985; Petitjean et al., 1992). This issue connects us to the status of institutionalization of the modern science fields in the colonial context.

COLONIAL INSTITUTIONALIZATION AND THE LIMITATIONS OF PROFESSIONALIZATION: One should distinguish between the first European colonization (from the fifteenth to the seventeenth centuries) and that of the latter period. During the first period, the adventurers were looking for trading posts rather than settlements and their knowledgeable companions suspected that they would come across monsters living by the boundaries of the known world: this was not the place for speculative exercises nor the time for transfers and organization of science—though scientists may have been useful in the day-to-day managing of the small colonies. Let us remember too, that 'modern' European science was at that time only beginning to take root.

The main contribution of colonial science took place later. It introduced modern science and techniques in the new empires, mainly through colonial enterprises, from the eighteenth century in Asia and Latin America and from the nineteenth century in Africa. Given the economic motives in the institutionalization of various scientific fields and their isolation from the local educational setting, the growth of science did not proceed at the same pace and did not follow the same paths as it did in the metropolis. While natural philosophy (as represented by the works of European naturalists in the colonies before the twentieth century), economic botany, economic geology, animal economy, among other colonial sciences, thrived unabatedly till the twentieth century, the deductive and experimental sciences struggled to find expression.

There are many cases in various colonial scientific enterprises which triggered the initial professional drive by opening specialist technical schools, but even here the imperial plan of action and the strictly pragmatic goals greatly limited the promotion of science in the interest of local conditions. The early history of the Royal School of Mining (created in 1792) in Mexico is a relevant instance. Spain promoted this institution in the discipline of mining as Mexican mines were strategic, for they accounted for 66 per cent of the world silver production. In the African case, as in the detailed account of copper production in the central African states shown by Headrick (1988), traditional technology was considerably upgraded and mechanized by 1910. Introduction of modern metallurgy by the British and the Belgians transformed the copper industry, but what is not clear from Headrick's analysis is the internalization of the 'stocks of knowledge' in the local industry in the following decades, as technical institutions did not come up till the 1960s.

There are some notable examples of professionalized efforts in science linked to the advancement of knowledge in the colonies of Africa, Asia and Latin America. Settler scientists in the case of Algeria and Argentina have won Nobel Prizes for medicine and the bio-sciences on account of discoveries which owed much to their local rooting; and an Indian won the same prize for physics in the 1930s. But these individual efforts were rarely sponsored nor undertaken by the main colonial science institutions (except for the Pasteur Institutes), and had indeed little to do with the bulk of the colonial scientific enterprises. In many cases, where the colonial scientific enterprises were linked to some form of professional pursuits, they were oriented towards the professionalization of science in the metropolis to a large extent (see Browne, 1992; Stafford, 1990). In the case of British India, many British naturalists, such as Hugh Falconer, who served in the colonial administration became experts and members of the Royal Society in Britain on their return from India. All this again is consistent with a general plan of action throughout the entire empire—the colonies were just provinces of an imperial body.

The non-development or late development of university and higher training centres in most of the colonial regions greatly hindered the lasting professionalization of the colonial scientific fields. There were severe limitations on the availability of local trained personnel, especially in Africa. For instance, according to the data presented by Eisemon et al. (1985) in the field of agronomy, at the time of independence the British colonies in tropical Africa had only 150 university graduates and the French colonies had only four.[2] Universities and educational settings, though they came up in many parts of the European colonies in the nineteenth century, did not become prominent centres to promote professionalized science till the beginning of the twentieth century. The university taking on this role, as we shall see in the next section, was mainly due to the efforts of the local elites from the beginning. More than any other factor, the development of local autonomous and legitimate communities of specialists was the main constraint under the colonial context.

AUTONOMY AND POLITICAL LEGITIMACY: It is needless to elaborate on the crucial importance of scientific autonomy, and political legitimacy and support in the formation of national scientific communities. One could conceptualize the character and role of state intervention at different levels of analysis. What we wish to emphasize here is the initial order of autonomy and political legitimacy for building a scientific community that is exemplified in the case of Japan after the 1870s by the Meiji elites. For about fifty years after this period, Japan systematically designed its trajectory of educational, university and technological structures to integrate the modern scientific and technological developments from Europe. Japanese scientists were sent all over Europe to bring back the potential knowledge and at the same time European scientists were invited to impart scientific and technical expertise to the locals. Such a scenario, particularly the political support and the purpose of scientific autonomy, was not present in the case of Asian and African countries till the 1940s and 1960s respectively.

The question of political legitimacy for the promotion of higher educational structures proceeding with scientific research becomes glaring when we compare the African and Latin American nations. The Latin American countries gained independence at least a century before the African states. As the chapter on Argentina by Hebe Vessuri in this volume shows, the establishment of the first full-fledged universities by the turn of the present century and development of medical and biological research institutions which resulted in the Nobel Prize in physiology for an Argentinean scientist in 1947, could not have been possible without the private aid and the political legitimacy rendered by the political elites. By 1918, Argentina had three long-established major universities at Cordoba, Buenos Aires and La Plata. They were then subjected to the university reform movement to create an appropriate institutional context and professionalize the sciences based on the French model. By the time of the centenary celebration of independence in 1910, the University of Buenos Aires already had 4,000 students who were organized in student centres of medicine (1900), engineering (1903) and law (1905), and continued to grow rapidly in the following half-century. These were also the years during which Argentina facilitated the cross-national diffusion of science from Italy, USA, Germany and France.

In the case of Brazil, the scientific missions of Dom Pedro II to the European scientific centres, particularly in France, beginning in the 1870s marked a conscious policy to transport the potential seeds of the European scientific and learning systems. Between 1875 and 1890 the imperial elite located in Brazil played a crucial role in providing the political legitimacy for the promotion of modern science in Brazil. For about forty years, until the 1930s, political support was channeled in several important directions: drawing scientists from all over Europe, reforming existing scientific institutions, and creating a demand for both applied and basic sciences with the establishment of the Brazilian Academy of Sciences in the 1920s and the University of Sao Paulo in 1930 through French connections in science—resulting in the first nascent Brazilian scientific community by the 1930s (see Schwartzman, 1992; and Botelho and Schwartzman in this volume).

In the case of the African states, the weak national movements and the relative absence of an intellectual elite, compared to India, could not derive political legitimacy to create a demand for the promotion of local scientific and educational structures. The major translocation of French science in Francophone Africa from the late nineteenth century up to the 1950s was the institutional radiation of six Pasteur Institutes in Algiers (1894), Nhatrang (1895), Madagascar (1902), Tunis (1903), Brazzaville (1910) and Dakar (1913). The prolonged phase of colonial institutionalization of scientific fields in local educational settings until the 1960s did not enable the African countries to embark on the building of a local scientific base till the 1970s. The availability of relative scientific autonomy in the case of many Latin American countries, such as Argentina and Brazil, despite internal political disturbances enabled these countries to chalk out their programmatic attempts to build local scientific and technical institutions, recurrently drawing support from European scientific circles from the late nineteenth century. It is a paradox that French scientific academies and the French model of 'Ecoles' for advanced training and research served as radiating influences in the Latin American countries more profusely and effectively than in French Africa. The loosening of the tentacles of Portuguese and Spanish mercantile colonialism much earlier than those of Anglo-French imperialism in Africa, and the factor of political and cultural legitimacy for the reception of modern science in Argentina, Brazil and other countries of the region, explain the relative difference in the formation of local scientific communities compared to the African countries.

The importance of political legitimacy for science leading to the reception of modern science and early development of 'Ecoles', universities and research institutes can also be seen in the case of Thailand, which was not under colonial control. As the chapter on Thailand in this volume shows, the fourth of the Charki dynasty kings, Mongkut (regarded as the father of Thai science) and his son Chulalongkorn, introduced modern reforms in administration, and social and economic spheres, and facilitated the introduction of all modern technological projects such as the railways by the 1870s. For about forty years, till the turn of the present century, the king's political support enabled the Thai elites to get their higher education in European countries. By the turn of the present century, the Thais had established their first full-fledged modern science educational institutions in medicine (1889), law (1897), engineering (1913) and agricultural training (1913), and in 1916 the first Chulalongkorn University came up. Together with the question of political legitimacy, the factors of long periods of expatriate domination in scientific structures coupled with the late development of university structures have been the problem in the case of the African countries more than in other regions.

EXPATRIATE SCIENTISTS AND THE PROBLEM OF IDENTITIES: This feature, in a large measure, has somehow transcended the historical writings on science, technology and colonization. From a sociological perspective in exploring the emergence of local scientific communities in the former European colonies, the question of expatriate scientists and the problem of identities however comes into sharp focus from the point of indigenization of colonial scientific enterprises. Expatriate scientists in the colonial scientific administrations in British Africa and Asia, French Africa and the Dutch Indies, numbering in thousands from the late nineteenth century spent on an average five to eight years in the same place. During the short periods of colonial service and stay in a particular colony, these researchers did not develop enduring commitments for the local regions, particularly for aiding the professionalization of the sciences. For the greater part of their stay these scientists lived in relative isolation from the local culture and social structures.

It was even so when such people stayed for a longer time. For instance, in the case of India, there are several scientific personalities such as Willian Brook O'Shaugnessy—indeed, a marvellous technical hand. He came to India in the 1840s and became a well-recognized professor of chemistry in a medical institution in the Calcutta Presidency. He was instrumental in laying 12,000 miles of telegraphy between 1857 and 1860 (the period significant for the First War of Indian Independence) and performed a perfect role of the 'scientific soldier' for the British Empire. But when his time for retirement came, he left India, and all that experience and knowledge gained were simply lost for the indigenous people in the colony. The professionalization of chemistry had to wait till the late nineteenth century when the first Indians (P.C. Ray, J.N. Mukherjee, and others) returning from British universities set out to develop higher research and established scientific societies.

With hindsight, it may be said that it was not such a serious problem in the case of India as there were local trained scientific personnel in thousands by the turn of the present century. The lack of local trained people and the domination of expatriate scientists however can be said to have been a serious setback factor for the indigenization of science in the case of African countries. We find that wherever expatriate scientists had a greater degree of local commitment and identity, their efforts have in a number of ways resulted in the development of local educational structures and the triggering of the professionalization of science. Such cases are, however, more difficult to find in the case of the African countries, with the exception of the missionaries and some figureheads of the Pasteur Institutes with limited spheres of influence.

Developing local scientific identities is an important feature for gaining legitimacy and political support. It was not problematic in the case of settler countries such as Brazil, Argentina and other Latin American countries. We may also include Australia here. Relative to the African situation, obtaining independence earlier provided a nationalistic framework for the development of science. It afforded considerable political legitimacy and autonomy for the initial efforts to host modern science and educational structures and facilitated the immigration of scientists from outside.

More than five hundred years of European colonization in Asia, Africa and Latin America had many consequences on the historical construction and structuring of modern scientific and technical institutions, both for the colonizer as well as the colonized. In the realm of intellectual ideas there are many paradoxes. One is that the European intellectual tradition which fought for the scientific autonomy and democratization of systematic knowledge over the medieval church, and for defending scientific knowledge against the obscurantist theological order and control, does not seem to have been a part of or to have penetrated the 'cultural matrix' of European colonial science. These ideas and tradition, however, found their way into the non-European cultures by other intellectual routes. What seems more probable is that colonial science—which was in fact the other face of imperialism—had redefined the tenets of Baconian 'philosophy', that is, knowledge as power, to render meaning to its political and economic goals. Empowering and disempowering are, however, simultaneous processes which get manifested in various forms. In fact, the ideas of centre–periphery, both in economics and the social history of science, express the results of such historical processes. Colonial science comes to an end with the Second World War (delayed up to the 1960s in the case of Africa), which triggered the disintegration of European colonial empires, paving the way for the creation of independent nation states and at the same time for underdeveloped economies, including science, in Asia and Africa.

A variant of this development can be found in the case of Latin America. A perceptive general remark of Petitjean (1992: 636) draws our attention: 'it is a paradox that the political independence of Latin American states transforms them into opportunities for European rivalries in particular between France and Germany'. In all probability we may add USA to the European list for the period extending into the post-War, during which its influence in Latin America has been the most dominant. More than anything else the Latin American countries, especially Mexico, Brazil and

Argentina, show that the factors of independence and political legitimacy are essential but not sufficient conditions for the complete emergence of effective scientific communities. Whilst the exploration of colonial science structures yields many important external explanations for the understanding of abortions in the formation of initial local scientific communities in the former colonies, the social, political and intellectual traditions which are specific and endogenous to the former colonies have in varying ways played the positive and negative roles of 'valorations' (in the case of Latin America see Saldana, 1987).

The National Mode of Scientific Development

In the nationalist mode of scientific development, the notion of *national science* signifies the conceptualization of scientific research in the broader interests of the country's socio-economic framework. Efforts are made to indigenize scientific institutions and research is carried out predominantly by local citizens. The agenda of research at the macro and meso levels, unlike that of colonial science, is not dictated by the remote centre of metropolitan imperial agencies but is evolved by the country's decision making process. As the Indian case shows, national science can take roots even within the colonial context. But the notion of a national mode of science as used here becomes more meaningful in the framework of nation states. Scientific activities serve either to concretize the idea of fair access to all sorts of scientific fields and achievements or help in nation-building activities. Science, however, is one among the other sectors of the economy and society involved in this process.

As the post-War experience shows, state intervention and mediation played an important role in the nationalist mode of science, as the finances for S&T greatly depended on the public purse. In many countries of Asia and Latin America, programmes in 'big science' and defence were given top priorities compared to civilian scientific research. In the case of the African countries, agricultural sciences were the main focus. Under the auspices of their governments, the countries of the South made efforts to develop infrastructure and S&T institutions including the promotion of national scientific communities. For almost three decades after the 1950s, the economic strategies followed in the South were dominated by the policies of import-substitution and self-reliance towards the goals of modernization and industrialization. These policies were legitimated on various grounds to sustain the process of indigenization and at the same time to guard against the deleterious impact of neo-colonialism and imperialism. S&T being looked on as the main instruments in the national developmental process, the policies had considerable bearing on national scientific communities. Local and national S&T efforts were thus protected through various regulatory and control mechanisms. Given the national socio-economic demands, greater emphasis was given on applied and development research more than on basic or fundamental research in the South. The ways in which nationalist sentiments at the political, military and economic levels influenced and structured intellectual achievements and the S&T systems varied from country to country and across different S&T fields within a single country. We shall further explore the features of the nationalist mode in the next section which covers the post-War developments in science in the South.

Towards a Privatized Mode of Scientific Development?

The South today is experiencing a new privatized and internationalized or globalized mode of scientific development in search of definition. In that context, certain economic measures are now more or less being implemented within the Southern countries. These are:

- Opening up of the national economy to competition coming from both local and external market forces. Appropriate policies are being introduced to dilute the protective policy measures.
- Privatizing government controlled industrial and service-oriented enterprises or reducing government stake and control in these operations.
- Liberalization of the non-capital and capital goods sectors from import tariff barriers across the industrial and market spectrum to promote exports and increase international trade.
- Redefinition of most of the economic policy measures and regimes such as patent policies and environment policies to fall in line with international regimes such as GATT and others.
- Introduction of new S&T policy measures to make publicly funded R&D more accountable and relevant to the new economic and market demands at the national and international levels. There are clear signals in most of the countries which suggest reduced public size of R&D funds and the increasing role in it by private corporations, including multinational corporations (MNCs).

Both the North and the South are facing on-going trends in globalization and privatization. But in so far as the sector of S&T is concerned, there are major implications for the South. The hierarchy of disciplines, the sources of scientific prestige and reputation, the yearning for research autonomy, and the very professional models and values are seriously being questioned in the newly emerging mode of scientific development. Scientific research as a commodity and secrecy in research results are assuming enormous significance in the new emerging scenario. Maximum connectivity between science and the sectors of production will be sought via programmes led by researchers on the very sites where potential user firms are installed. The values of the scientific community in publicly funded scientific agencies are likely to be disrupted. Success will increasingly be measured by the contracts obtained, research products released in the market, and the extent to which research groups and individual scientists can successfully play in the big league of science as a commodity rather than in its contribution to education and the advancement of knowledge. Publicly funded science which is linked to welfare and services is likely to operate on more commercial lines, imposing greater tariffs on the general public in the future. In parallel to the *industrialized science* as put forward by Ravetz (1971), there are already signs of a new *consumer science*, as termed by Nakayama (1991). In any case, the new situation of globalization and privatization is likely to bring about a change in the value systems of the scientific communities but does not make this concept irrelevant. Rather the new situation with a spectrum of new technologies calls for greater attention to new strategies of professionalization and the development of inter-disciplinary specialist groups. We shall further look into this aspect in the next section.

Post-War Expansion of S&T Structures: From Optimism to Disenchantment

With the exception of the African states, the indigenous initiatives in building national infrastructure in S&T and strengthening the base for scientific communities in most of the countries of the South began immediately after the Second World War. The two Wars in a way were a blessing in disguise which led to the development of war-based scientific and technical activities in many countries. The wartime preparations also led to the development of initial infrastructure in countries such as Brazil, India, Argentina and Egypt and in some other African states. In reaction to the colonial economic and scientific dependency, most of the developing countries, as pointed out earlier, adopted the nationalist mode of scientific development. The policies of import–substitution and self-reliance governed the directions in S&T. At the same time, the political and intellectual leadership in many countries were greatly inspired by the modernization theories coming from the West. The efforts in developing science infrastructure were largely legitimated by such policy options on the one hand, and grounded in the visions of creating modern societies and transforming the traditional non-rational structures on the other hand. The model and reference point for the South, however, was that of the Western industrialized countries.

The power, hegemony and above all the sustained economic growth coupled with the material wealth in the West infused unbounded optimism about science for growth and development in the leadership of many countries in the South from the 1950s to the 1970s. Nehru in India, Nasser in Egypt, the Party leaders in China and other political elites in varying ways expressed optimism in building a modern S&T base. The creation of international agencies such as UNESCO and others in this period played a significant part in generating the consciousness for promoting S&T infrastructure. Through various international meetings these agencies also influenced the creation of science policy structures in the developing world. In the specific case of Latin America, as Sagasti (1990) points out, the US National Academy of Sciences, UNESCO, the Organization of American States and others produced reports which encouraged and legitimated the governments in these countries to infuse greater resources for promoting local S&T infrastructure. The 1963 UN Geneva 'Conference on the Application of Science and Technology for the Benefit of Less Developed Areas' provided an additional dimension by suggesting that the accumulated stock of S&T knowledge could be used as a 'vast supermarket' by the developing countries in tackling their development problems. Historically speaking, a combination of international discourse and the optimistic visions emanating from both the political and scientific leadership of the South (1950s to 1970s) also presupposed an unproblematic relation between science and development, especially for overcoming the stage of underdevelopment and 'Third Worldness'. Homi Bhabha (better known as the Father of the Indian Atomic Energy Programme and who wielded considerable power in the political corridors of Nehru) in 1966 reflected:

> What the developed countries have and the underdeveloped countries lack is modern science and an economy based on modern technology. The problem of developing the underdeveloped countries is therefore the problem of establishing modern science in them and transforming their economy to one based on science and technology (Bhabha, 1966: 541–42).

Bhabha was not alone in reflecting such comparative scenarios of the developed and the underdeveloped economies in terms of S&T endowments. Such a stream of thinking permeated the developing world, which led to the building of infrastructure and an institutional base in science for over two decades after the 1950s in the image of Western industrialized countries. Budgets and stocks of S&T personnel witnessed considerable increases compared to the colonial and pre-War period. This was also a period which witnessed the establishment of science policy organizations and mechanisms in government departments, and the creation of ministries in S&T, deriving the model from the developed countries. This period signifies the perspective of policy for science for a number of developing countries. Universities, full-time research laboratories, and science academies and societies including local and national journals were created in almost all the developing countries. There was a dramatic growth of universities and educational institutions with corresponding enrollments in S&T compared to the colonial era. Even though the degree of professionalization of various scientific disciplines and fields varied greatly across the countries of the South, the institutional conditions conducive for the promotion of professional science were created as a result of the policies for science. Many countries such as China, India and Argentina could enter the privileged nuclear, space and defence clubs by the 1970s due to the impetus given to these fields of research during the two decades after the 1950s.

More than anything else, the optimistic expectations in the 1960s deemed modern S&T as a panacea for most of the problems of poverty, modernization and industrialization. It was indeed a romantic mood which reflected that once modern S&T institutions were established, universities created and S&T policies chalked out with appropriate budgets for science and industry, development would flow. In this period, a number of countries from the South embarked on the path to industrialization, and sought massive purchases and transfers of technology from the industrialized countries. With the establishment of a local S&T base, the economic policies and political justifications in the developing world also assumed that the strategies of import–substitution would eventually ease the dependency syndrome and new research capacities would be created, as in the case of some developed countries. The underlying assumptions did not envision the practical connections between the university, full-time research laboratories and the industrial sector (especially the private one) as being problematic. Till about the 1970s it would not be an exaggeration to say that the greater part of the South sailed in the same boat in so far as the optimism thesis is concerned. The chapters in this volume illustrate different versions of this hope of the 'Great Leap Forward' up to the mid-1970s.

The optimism and euphoria of the 1950s and 1960s were not aligned with the expectations at the socio-economic ground level and met with criticism coming from various groups. The criticism over S&T soon led to a form of disillusion and disenchantment as the economic crises and unemployment problems deepened. The oil crisis in the 1970s worsened the situation and further fuelled the sentiments of criticism over science, and the Western models came to be viewed with considerable suspicion. The appropriate and alternative technology movements, including the counter science sentiments which emerged in the 1970s, are to some extent indicators of the disenchantment trend. Concerns were also expressed in many countries of the South about the possible risks and abuses resulting from the scientific and technical collaborations with industrialized countries. The role of global corporations was vehemently criticized in Latin America and Asia. Added to these was the issue of brain drain which created serious problems for the South and also questioned the developmental models followed up to the 1970s.

The failure of the 'trickle-down' theories, which to a large extent legitimated the earlier optimism, came in for sharp criticism in the developing world from various quarters. As a recent UNESCO document (1992: 5) points out,

> even when aggregate economic growth rates have been high, the distribution of the fruits of growth has not been satisfactory. Real wages and incomes of the majority of the population in developing countries have, at best, stagnated. Rather than strengthening democracy, development programmes based on the 'trickle down' paradigm contributed to social unrest and upheavals.

Even if the question of social unrest is difficult to directly relate to the factor of S&T, the unequal profits of science-induced results, when injected from the top into development, are borne out to some extent by the Green Revolution. But the problem seems to be glaring with regard to many high technology and 'big science' programmes, and it is expressed by several political and scientific circles in the countries of the South. The 'magic' of S&T started to lose its shine from the mid-1970s. The UN conference in Vienna in 1979 represents a turning point. It marked the beginning of a period of more sober realism about the limitations of science and development in the South.

Whilst the South experienced a severe crisis in realizing the fruits of S&T from its nationalist and endogenous perspectives, the period of the 1980s posed new types of challenges with the 'revolutionary' emergence of new technologies, as pointed out earlier. International firms and institutions which became major players in these technologies were those who controlled and commanded the resources for basic science as well as highly skilled personnel with sound basics. Inter- and multi-disciplinary teams of researchers with corresponding professional strategies to combine academic and industrial goals in relation to market locale in the field of new technologies signalled new challenges in science for the South.

Developing countries which were endowed with good universities and which built up research groups with a certain degree of excellence in the field of new technologies proved to be better placed to derive social and economic benefits. Implications were clear for the Southern countries: as far as possible, they had to give a marked priority to the promotion of professionalization of specialist groups in the new technology fields and also to developing institutional mechanisms to induce inter- and multidisciplinary teams. For some countries like India, China and Brazil, which have developed specialist groups and research laboratories, the task was to bring about industrial and commercial linkages. For the South-east Asian countries the tasks lay in strengthening the former domain. Whilst for these countries the new tasks were surmountable in one form or another, the African states had to prepare to be further engulfed in an enhanced crisis.

In the 1990s, environmental awareness which culminated in the 'Earth Summit' in Rio in 1992 certainly added to the wave of pessimism and crisis, while at the same time the hopeful idea of a 'natural contract' between Man and Nature was taking shape (Serres, 1990). It also reinforced the conviction that scientific development should be considered in terms of its long-term impact and that the solutions of environmental problems required the mobilization of the world around collaborative efforts. Yet, as stated in a recent World Bank report (1992), 'the most immediate environmental problems facing developing countries . . . are different from and more immediately life-threatening than those associated with the affluence of the rich countries'. The negotiations which took place at Rio clearly reflect the divergence in the perspectives and solutions between developing and industrialized countries.[3]

Institutionalizing environmentally benign techniques being a future challenge to the South, the current wave of the privatization and globalization mode has further accentuated the problem of sustaining local research capacities in the South. Not only does the liberal import of technology and products stand to threaten the local, national R&D capacities, but publicly funded research in the South is subjected to new competition from private corporations and foreign MNCs who are transferring or opening up R&D facilities in the South due to higher costs in the North (and with the support of local governments seeking to localize frontier industrial knowledge in their countries). This new competition is, however, not confined to new technologies but is widely spread in the conventional manufacturing sector: here the North is boosting research to recover market shares by improving the quality of its own domestic production and reducing its costs through automation. The South is however caught up in a double bind situation. While its manufacturing activities carry higher threshold levels of pollutants, at the same time, transformations in the institutional settings for conducting scientific and technological activities and in the patterns of interactions between different actors involved are taking place. New partnerships between government research agencies, universities, private industry, non-governmental organizations and community associations are being advocated and implemented. While direct government control in S&T activities is getting reduced, scientists are being pressed to go to the market (Vessuri, 1994). There is also strong pressure to transform the overall S&T system from a supply driven to a demand driven system. The financing of science and higher education, which has been a government responsibility since the colonial period often supplemented by foreign donor agencies, is in deep crisis in many countries of the South, notably in Africa and Latin America (see the chapters on Kenya, Nigeria, Senegal and Venezuela in this volume). In many countries, government research institutions and public universities are pressed to raise a significant part of their budget from private sources and privatization is often presented as *the* solution to the financial crisis.

The question is not merely how to reorganize scientific communities and bring about linkages with the production sector. The crisis in the South during the 1980s and early 1990s has led to the questioning of the conventional S&T policies followed thus far, as many solutions to the challenges thrown up by the new situation seem to lie outside the scope of these old policy spectrums. The input-oriented science policy regimes in the countries of the South have also drawn considerable criticism from the research studies on innovation. These studies have shown that success in innovation has a large component of institutional, organizational, and non-R&D technical functions and skills which have not formed a part of the conventional science policy explanations. R&D, as it is generally understood, is revealed as one important component in the success of innovation as a whole. Further, as Salomon (1994) summarizes:

> . . . the problem of innovation depends less on the size of the investments in research and development than on basing the management of university and industrial resources on the entrepreneurial model. By emphasising the importance for the innovation process of these factors which are not properly scientific or even technical, all these studies recommended concentrating on policies that at first sight appear to have little in common with science policy as such. They stressed that it is not enough for a country to have excellent universities and research teams, to turn out increasing numbers of Ph.Ds, to devote vast resources to R&D activities, not even pile up Nobel Prizes in order to be one of the leading innovators. Winning the productivity battle, capturing and keeping new markets and developing full potential for innovation does indeed require a well-run research system, but that is just one element, one prerequisite among many others.

In other words, mere administration of science is no longer adequate and the broader understanding of innovation beyond the 'duty' of simply doing research calls for multiple links or networking between different actors and agencies from science to the market. What is also essential is the ability to learn from the hindsight experiences of successful cases and countries, both from the developed and the South-east Asian contexts. The emergence of new innovation policies in the context of the North came about during the late 1970s and 1980s in the wake of new technologies. Learning from the successful experiences of some of these countries on innovation policies and the role of governments (in particular, the cases of South Korea and Taiwan) offers many new 'windows of opportunities' for a limited number of Southern countries. Many others could and should strive to imagine ways of appropriating and making at home the best use of know-how and knowledge from which none may now get away—however unfamiliar they may look (including bio-technologies or the techniques of production in small series adapted to defined target markets).

The question is whether these countries have the will, imagination and lucidity to steer such a course. The newly emerging innovation systems, often termed as 'techno-economic networks' or 'paradigms' in the North, are likely to further increase the gap between the North and the South (Pereira, 1994). It is at the same time more likely that a new segment of the Southern countries, which are referred to as the newly industrializing countries, might in the next century occupy a middle position. In any case, the contemporary crisis of science and economy in the South must not be viewed with absolute pessimism. As Brundenius and Göransson (1993) draw our attention to the Chinese dialectical approach, the word *crisis*, or in Pinyin *wei-ji*, is composed of two notions—*danger* (wei) and *opportunity* (ji). While the crisis of science in the South is posing new challenges—often in a threatening mould—there is an opportunity to learn new lessons. The capacity to learn new lessons and absorb successful experiences in the reorganization of S&T systems calls for a greater role of STS studies.

Mechanisms for international cooperation in S&T have also changed greatly over the last decade, and their imperative necessity is exacerbated by the rising costs of training, maintaining and reproducing national scientific communities as well as of sustaining S&T systems. International connections are playing a pivotal role in enabling the best groups to continue doing science (see in particular the chapter on Nigeria). On the part of the foreign donors, these mechanisms have evolved greatly over the last few decades from technical assistance to collaborative research partnerships (Gaillard, 1994). As a consequence of the greater importance given to environmental concerns, assistance is also being increasingly linked to the consideration of environmental objectives. But North–South collaborations in science remain on the whole a peripheral concern of industrialized countries. The end of the Cold War also signalled a decline of interest among the main donors and a shift of interest towards Eastern Europe and the newly independent states of the former Soviet Union. In the South, while some expatriate scientists are taking the decision to return back home (mainly to the so-called newly industrialized countries), new networking mechanisms are being implemented to optimize the cooperation of migrant scientists for the benefit of their home countries. Thus, international scientific migrations are beginning to be considered from a different perspective and the concept of the national scientific community itself is being revised so as to include those scientists who had left their countries and gone to work elsewhere. New institutions for regional cooperation in S&T are also being envisaged and established.

In this process, the roles of scientific communities are also changing. It is, however, a necessary but not a sufficient element in the development process. As stated in the concluding section of the chapter on Thailand in this volume, the roles of scientific communities 'are likely to become increasingly diversified in coming years, as this community is called upon to provide training, policy guidance, service to a variety of constituencies, in addition to evidence of excellence in the production of science'. But the apparent similarities of the problems confronting the developing world should, however, prevent us from treating them as if they were a homogeneous entity. The different case-studies presented in this volume clearly illustrate the diversity of situations. Although they provide elements of comparison, the aim of this volume is not to provide a universal explanation or a unique model to follow. Its aim is merely to contribute to a better understanding of the conditions under which scientific communities have emerged, developed and are often struggling to sustain their activities, as well as an understanding of their changing roles and their connectivity with the rest of society in different contexts. Towards the close of this chapter, we intend to highlight the two issues of the stratification of countries in the South and their position in mainstream science, including the international context.

How Many (Third) Worlds?

The last decade has made it increasingly clear that there is not one but several 'Third Worlds'. But, the concept itself of a 'Third World'[4] which became more and more commonly used during the 1960s and the 1970s in the context of the West–East confrontation—the 'First World' representing the 'capitalist countries' or the 'Western World' and the term 'Second World' being used to indicate the former 'Communist Bloc'—is becoming meaningless in the post-Cold War era. The term 'Fourth World' has also been used for the 'least (or less) developed countries'. The growing emergence of another 'Fourth World', or the so-called 'nouveaux pauvres', in the industrialized countries in analogy to the poor of the 'Third World' is an additional indication that this typology is no longer appropriate on the eve of the twenty-first century. We also share the view of Gunnar Myrdal that the term 'developing' countries, which replaced 'under-developed' countries following a process referred to as 'diplomacy by terminology' in his *Asian Drama* (1968), is illogical since it implies that some countries are developing and others are not. In the absence of a better term we will, however, continue to use the term 'developing countries' in this volume.

The last decade has also shown that the gap between the 'least developed countries' and the 'newly industrializing countries' is clearly widening. The latter have reached a fair level of technological and scientific research, industrial capacity and domestic standards of living which justifies their hope to better capitalize on new scientific developments and technologies (Yanchinski, 1987), while most of the least developed countries have unproductive, inadequate scientific research systems, and lack an industrial base, qualified personnel and capital.

In the mid-1980s, seven developing countries (Taiwan, Korea, Hong Kong, Singapore, Brazil, Mexico and Argentina) accounted for almost 90 per cent of the total manufactured exports of the developing world, and the four in Asia close to 80 per cent. Although the development of endogenous scientific communities has not been the impetus for development in most of the newly industrializing countries in Asia, these countries are now trying harder than ever to develop their national S&T activities. In the late 1970s and early 1980s, when most developing countries were generally devoting between 0.1 per cent and 0.4 per cent of their GNP to research, Korea, for example, was already spending over 1 per cent and in the 1990s is spending close to 2.5 per cent. Singapore, which is lagging slightly behind, starting from an average level of spending characteristic of most developing countries in the late 1970s and early 1980s (between 0.2 per cent and 0.3 per cent) is now spending more than 1 per cent and is planning to catch up with Korea and Taiwan before the end of the century (Goudineau, 1990). A similar development might take place in the South-east Asian countries (see the chapter on Thailand in this volume) during the coming decade, although their economies will no doubt remain more dependent on agriculture. This situation is clearly different for the remaining Latin American industrializing countries (Brazil, Mexico and Argentina) which, unlike their four Asian counterparts, belong in the category of large countries.

The question of the large countries is more difficult because of the size of their scientific communities and because most of them can hardly be considered as single entities but rather as several countries in one. One should, however, distinguish here between the two giants (China and India) and the other countries (Indonesia, Brazil, Mexico, etc.). India, which has been described as 'excellence in the midst of poverty', today has one of the five largest scientific communities in the world and accounts for close to 50 per cent of the scientific production of the developing countries. China, like India, also has a very high scientific and technological manpower potential in absolute terms due to its huge population, but low as a percentage to the total population. Both countries have vast regional disparities. The development of the scientific community in Brazil—the largest scientific community in Latin America—also illustrates the profound regional imbalance between the southern states (and more specifically the state of Sao Paulo) and the rest of the country. But large often goes together with fragile (Shiva and Bandyopadhyay, 1980), and the economic difficulties recently experienced by most of these countries plus the political events which arose in China remind us that the future of their scientific communities is far from secure. They still have to struggle to create a space for science (Schwartzman, 1992).

But let us remember that the majority of the developing countries are small and very small countries. In 1985, about 67 per cent of all developing countries had a population of less than 10 million, and 52 per cent had less than 5 million. The case of Senegal in this volume is a typical example. Although size, measured in absolute terms, is not an adequate indicator of the prospects for developing an S&T base, it is more difficult to establish one in the smaller countries. Due to resource constraints, small developing and developed countries cannot solve all their problems alone. Major decisions have to be made as to what should be attempted using their limited research capabilities and what can be borrowed from elsewhere. This also requires adequate access to information and participation in research networks.

Thus, it is no longer possible to consider the developing countries as a single entity, and there is an obvious need to revise the existing typologies. An analysis of those available shows that the most common are linked to economic indicators, especially per capita GNP, and suggest classifications based on thresholds, e.g., the World Bank typology, which recognizes low income countries (with a GNP per capita of $635 or less in 1991), the lower-middle income countries ($636–2,499), upper-middle income countries ($2,500–7,910) and high income countries ($7,911 and more). The United Nations system, especially UNCTAD, makes a distinction between newly industrialized, oil-exporting, and least developed countries.[5]

But, as correctly stressed by Salomon and Lebeau (1988: 51), 'purely economic definitions of developing countries tend to be distorting mirrors'. Based on S&T resources, they proposed a classification with five categories of developing countries. A recent report presented to UNESCO by the International Council for Science Policy Studies (1990) proposes an aggregate typology of 'science and technology capabilities'. Excluding the industrialized countries, three groups are identified: those with almost no S&T base; those with fundamental elements of such a base; and those with an established S&T base. Most African countries belong to the first group.

The latter classifications are the most interesting ones for our purpose, but a number of misgivings suggest that further research and efforts are needed to produce a more dynamic typology that takes account of recent setbacks and fluctuations. The main reason is the lack of reliable, comparable and recent data on some of the basic indicators, including S&T activities, in many developing countries. The adequacy of some of the S&T indicators is also very much open to question. Furthermore, many of the crucial factors which affect a society's ability to take advantage of modern science cannot be measured and translated into indicators. The search for a more 'explicative' typology must extend beyond quantifiable indicators to include social structures, political systems and national history.

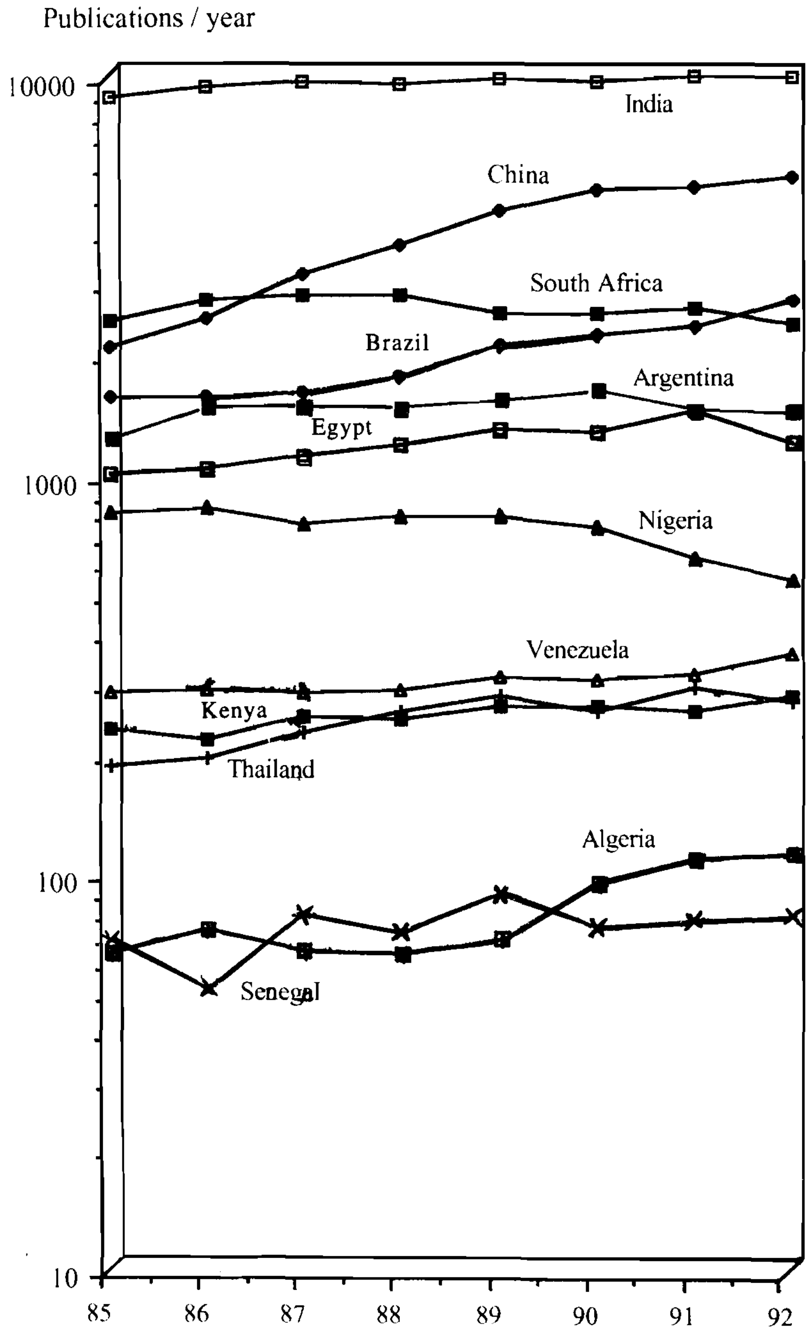
Relative Position of the Countries under Review in Mainstream Science

It is now widely accepted that the picture of Third World countries' scientific production has been distorted by the use of overly selective bibliographical databases. Yet, despite their shortcomings, which have been addressed elsewhere (Gaillard, 1989; Arvanitis and Gaillard, 1992),[6] international bibliographical databases—such as the database of the Institute for Scientific Information (ISI) which is the most commonly used in bibliometric studies—provide interesting information on the relative position of the various countries on the mainstream science supplier list (Frame et al., 1977; Garfield, 1983). The first conclusion is that mainstream science production, as reflected in the ISI database, is even more narrowly concentrated in a few countries than is national wealth expressed as GNP. Ten countries produce more than 80 per cent of the international scientific literature. Except for India, which has maintained a steady eighth place since the beginning of the 1970s, all other countries are members of the industrialized world. Thus, developing countries have long been credited to represent only 5 per cent of the world's mainstream scientific output, of which close to 80 per cent would be produced in Asia. Their share is today approximately 7 per cent, thanks to the dramatic increase of a number of Asian countries (mainly China, Taiwan and South Korea). The twelve countries presented in this volume (including South Africa) represented 5.2 per cent of the world's mainstream scientific output in 1992. Even if we challenge the representative value of these estimates, especially considering the database used, we still have to accept that mainstream science produced by the developing countries is marginal compared with the rest of the world.

Among the developing countries, India is the uncontested leader, but its position may soon be threatened by the People's Republic of China if the trend observed over the latter part of the last decade continues during the present decade (see Figure 1.1).[7] While India's mainstream production has increased at about the same pace as the total world output from 1985 to 1992, China has meanwhile experienced a drastic and quasi-constant rise. China's mainstream production thus nearly tripled and in 1992 represented more than half of India's. Brazil has also nearly doubled its mainstream production over the same period overtaking South Africa and leaving behind Argentina and Egypt, which used to be in second and third positions respectively after India in the early 1970s.

But the country which experienced the most drastic decline, particularly over the last few years, is Nigeria. It, however, remains the most important mainstream scientific producer in Africa, ahead of Kenya. Except for Algeria and Senegal, most of the countries presented in this volume belong—with different levels of participation—to the 'leading' science

FIGURE 1.1
Mainstream Scientific Production of the Countries Under Review, 1985-1992



Source: OST (SCI base and COMPUMATH/ISI) producers among the developing countries. But the per country mainstream scientific production (and more so the per scientist mainstream scientific production) remains small, even for some of the countries at the top of the list. A comparison with the production of scientific institutions in the OECD countries shows that a country such as Egypt produces less than the Harvard University Medical School (Frame, 1985). The total production of Sub-Saharan Africa (excluding South Africa) at present represents about one-tenth of the scientific production of a European country such as France.

The 'Global' Scientific Community in the International Context

Yet, in an era of globalization of scientific activities, considering only the mainstream scientific output produced by the researchers of a given national scientific community to characterize its size, style or potential gives only a partial picture of reality. First, the science 'useful' to a given country is not limited to science produced within its boundaries. The bibliometric study presented in the chapter on the Nigerian scientific community illustrates this first proposal.

Second, a national scientific community is not limited to the members present in that country at a given time. Many of them—and this is certainly the case for India, China and Egypt among others—are studying or working abroad. This does not mean that they cannot contribute to their country's scientific development in some way or that they will never come back. Thus, a number of countries in Asia and in Latin America have indeed started to rethink the problem of brain drain and tend to consider that working abroad for a while can represent a gain to the home country, rather than a loss, if the scientist returns with increased skills directly related to the needs of national research groups. Countries with a higher rate of brain drain have sometimes experienced rapid development, while countries with a lower rate of brain drain have developed more slowly. The role of expatriate Indian scientists in the development of molecular biology in India is a good example. The case of the People's Republic of China is of a different nature. Until recently there was no brain drain problem in China (Orleans, 1988; Pedersen, 1992). Since the Tiananmen Square repression, however, many Chinese studying abroad and in particular in the United States have tended to delay their return to China. And, 'it is still unclear whether the present situation of "delayed return" will result in a permanent brain drain' (Pedersen, 1992: 6).

Third, many research problems can increasingly only be addressed through international cooperation. Although the main responsibility for scientific development rests at the national level, there are numerous options through which international cooperation can contribute to this objective. An innovative way is to organize and link the community of national scientists living abroad with the national scientific community around scientific activities of common interest.[8] The 'Caldas network' of Colombian scientists, engineers and other intellectuals working abroad linked to the Colombian scientific community through electronic mail is already operating around locally organized 'nodes' in many countries (Meyer, 1994). The Latin American Academy of Sciences (ACAL), with the support of UNESCO, the International Council for Scientific Union-Committee for Science and Technology for Development (ICSU-COSTED) and the National Research Council of Science and Technology (CONICIT) of Venezuela, has also developed databases and information systems with a view to implementing the concept of a 'global scientific community' (Villegas and Cardoza, 1994). A number of societies of scientists abroad have also been established lately. An example is the Society of Chinese Bioscientists in America (SCBA) which has grown from 200 members in 1985 to 1,500 in 1993. This society is one of a growing number of organizations for Chinese-American scientists and engineers that serve as informal links to researchers and research communities in Asia.

Notes

1. Exceptions do exist. The most recent and comprehensive book on the subject is *The Uncertain Quest* edited by Salomon et al. (1994). Yet, this book has a more global approach, different objectives and different target groups. As recognized by the editors themselves, 'authors were asked to examine the issues through "small windows" and from just a few angles' (ibid.: xv) and a choice was made not to include country case-studies, thus making the latter book very much complementary to this one.
2. This is not very surprising since the first French-speaking university to be established in Africa was the University of Dakar in 1957, and this University had no Faculty or Department of Agronomy (see the chapter on Senegal in this volume). Yet a number of African scientists were trained by specialized French research institutes before and at the time of independence. As a way of illustration, ORSTOM trained thirty African scientists between 1957 and 1960 (ORSTOM, personal communication).
3. For a detailed discussion see Sachs (1994).
4. For a detailed discussion on the origin, definition and usage of the term see Wolf-Phillips (1987).
5. One could also refer to more comprehensive classifications taking into account the expansion of the world economy and of state driven development strategies. See for example Ominami (1986).
6. International scientific databases, and in particular ISI, are highly selective, and bibliometric studies based on their data bear on a small proportion of the world's science. Further, the scientific journals published in developing countries are rated as 'backwood cousins' in the ISI database, which includes barely 2 per cent of them. French publications, together with publications that are not in English, are at a disadvantage. The question of adequately representing science produced in the developing countries in international databases was the main point at issue at a 1985 conference organized at ISI in Philadelphia. The title of the final conference report, 'Strengthening the Coverage of Third World Science', pointed

to a glaring gap (Moravcsik, 1985). Actually, as Frame (1985) correctly pointed out, it all depends on what one is trying to assess.

> If the purpose of the bibliometrics indicators is to help in the building of a national scientific inventory, telling us what kind of research is being performed at different institutions, then coverage of local as well as mainstream publications would seem important. On the other hand, if one is primarily interested in investigating Third World contributions to world science, then publication counts taken from a restrictive set would seem most appropriate (p. 121).

7. This scientific output from the People's Republic of China was completely ignored in the 1973 ISI database (except for one publication). The powerful emergence of this country at the end of the 1970s was due to three independent phenomena: (*a*) increased contact with Western science, (*b*) a sharp rise in the number of scientific journals published in the country, and (*c*) ISI's stated decision to correct the non-representation of that country in its database.
8. The ability to organize such networks is of course dependent on the level of internationalization of a given scientific community. Thus, the Thai scientific community which, as shown in this volume, is not highly internationalized, is much less likely to organize such a network than India.

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