# scientific communities in the developing world

EDITED BY

Jacques Gaillard
V V Krishna
Roland Waast

# Scientific Communities in the Developing World

# Scientific Communities in the Developing World

Edited by


**Jacques Gaillard**
**V.V. Krishna**
**Roland Waast**



**Sage Publications**
*New Delhi/Thousand Oaks/London*

First published in 1997 by

**Sage Publications India Pvt Ltd**
M-32, Greater Kailash Market I
New Delhi 110 048

**Sage Publications Inc**
2455 Teller Road
Thousand Oaks, California 91320

**Sage Publications Ltd**
6 Bonhill Street
London EC2A 4PU

Published by Tejeshwar Singh for Sage Publications India Pvt Ltd, phototypeset by Pagewell Photosetters, Pondicherry and printed at Chaman Enterprises, Delhi.

**Library of Congress Cataloging-in-Publication Data**

Scientific communities in the developing world / edited by Jacques Gaillard, V.V. Krishna, Roland Waast.
p. cm.
Includes bibliographical references and index.
1. Science—Developing countries—History. 2. Science—Social aspects—Developing countries—History. I. Gaillard, Jacques, 1951– . II. Krishna, V.V. III. Waast, Roland, 1940– .
Q127.2.S44 306.4'5'091724—dc20 1996 96–17807

ISBN: 81–7036–565–1 (India-hb)
0–8039–9330–7 (US-hb)

**Sage Production Editor**: Sumitra Srinivasan

# Contents

# List of Tables

# List of Figures

# Preface

The project on which this volume is based was constituted by the Science, Technology and Development Group of the French Institute for Scientific Research and International Cooperation (ORSTOM), Paris, and the Sociology of Science Group of the National Institute for Science, Technology and Development Studies (NISTADS), New Delhi, during 1990–1991. The ORSTOM Group organized two international workshops during this period on the theme 'Emergence of Scientific Communities in the Developing Countries'. The first workshop was organized at ORSTOM, Bondy, France, during 21–25 April 1990; and the second one at Annaba, Algeria, during 24–31 May 1991 in collaboration with the Centre for Research in Applied Economy and the Upper Institute of Management of Annaba. About thirty scholars working in the field of Science, Technology and Society (STS) studies in the context of developing countries participated in these two workshops to discuss various issues relating to the institutionalization and assimilation of modern science and technology (S&T), professionalization of science, and the growth and effectiveness of scientific communities in the countries of Asia, Latin America and Africa. While the first workshop was useful in exploring the status of S&T in the developing world, the emergence and effectiveness of scientific communities was the focus of the second workshop in Annaba. The deliberations at this latter workshop led to the realization that despite considerable growth in the fields of social history of science and science policy studies, our understanding of the emergence of scientific communities in the developing world is quite limited, and one rarely comes across focused research material on this theme dealing with various countries in a single volume. Thus, the idea of the present volume emerged at this meeting. However, only five out of about twenty-five papers presented at these workshops have been selected for this volume. Other papers dealing with different themes are being published as workshop proceedings from ORSTOM.

The chapters on India, Algeria, Senegal, Brazil and Venezuela presented at the two workshops were subjected to several revisions before reaching their present form. Given the limited expertise represented at the workshops, the editors of the volume invited established scholars working on China, Kenya, South Africa, Thailand, Argentina, Nigeria and Egypt to contribute to this volume. In the process of working together on various themes concerning the problem of the emergence of scientific communities in the developing world, we have constituted an informal network called ALFONSO. The members of this network have been in recurrent contact for the last three years by making use of various international conferences. The main objective of this network is to promote the field of STS studies in the regions of the developing world.

Some of the contributions to this volume were originally written in French and Spanish and have been translated into English. This process consumed more time than we envisaged in 1992, which has delayed the completion of this volume. The editors of the present volume assume complete responsibility for any 'errors' or omissions still deserving attention.

Many friends, individuals and institutions have extended recurrent support and cooperation for the project and this volume during the last three years. We wish to particularly acknowledge the support of ORSTOM and Maison Des Sciences De L'Homme, Paris, and NISTADS, New Delhi. Without the recurrent support of these three institutions, the project and this volume could not have been launched. The Science, Technology and Development (STD) unit of ORSTOM, Paris, ORSTOM Office, Bondy, France, and the International Scientific Collaboration unit of the Council for Scientific and Industrial Research (CSIR), New Delhi, have supported the project directly or indirectly in various ways. We wish to thank our friends in these offices. Many friends have helped us in one form or another during the preparation of this volume. We wish to particularly thank Maurice Aymard, Jean Racine, Ashok Jain, Shiv Visvanathan, B.K. Ramprasad, Yves Goudineau, Philip Tarik, Cecil Dupont, Kapil Raj, Patrick Petitjean, Michael Patty, Catherine Jami, Ann Marie Moulin, Bernard Schlemmer, S. Irfan Habib and M.A. Wahid.

The process of coordination between the editors and the contributors to this volume, and amongst the three editors themselves, has not been an easy task. We were dealing with people and institutions across different parts of the globe. While regretting the delay in publishing this volume, we wish to express our sense of gratitude and thanks to all the contributors to this volume for their patience and support. We appreciate the efforts of SAGE, New Delhi, in bringing out this volume. We also wish to thank Harsh Sethi of SAGE for his meticulous editorial support.

**The Editors**

# 1 Introduction: Scientific Communities in the Developing World

**Jacques Gaillard, V.V. Krishna** and **Roland Waast**

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 'techno-sciences'. 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.

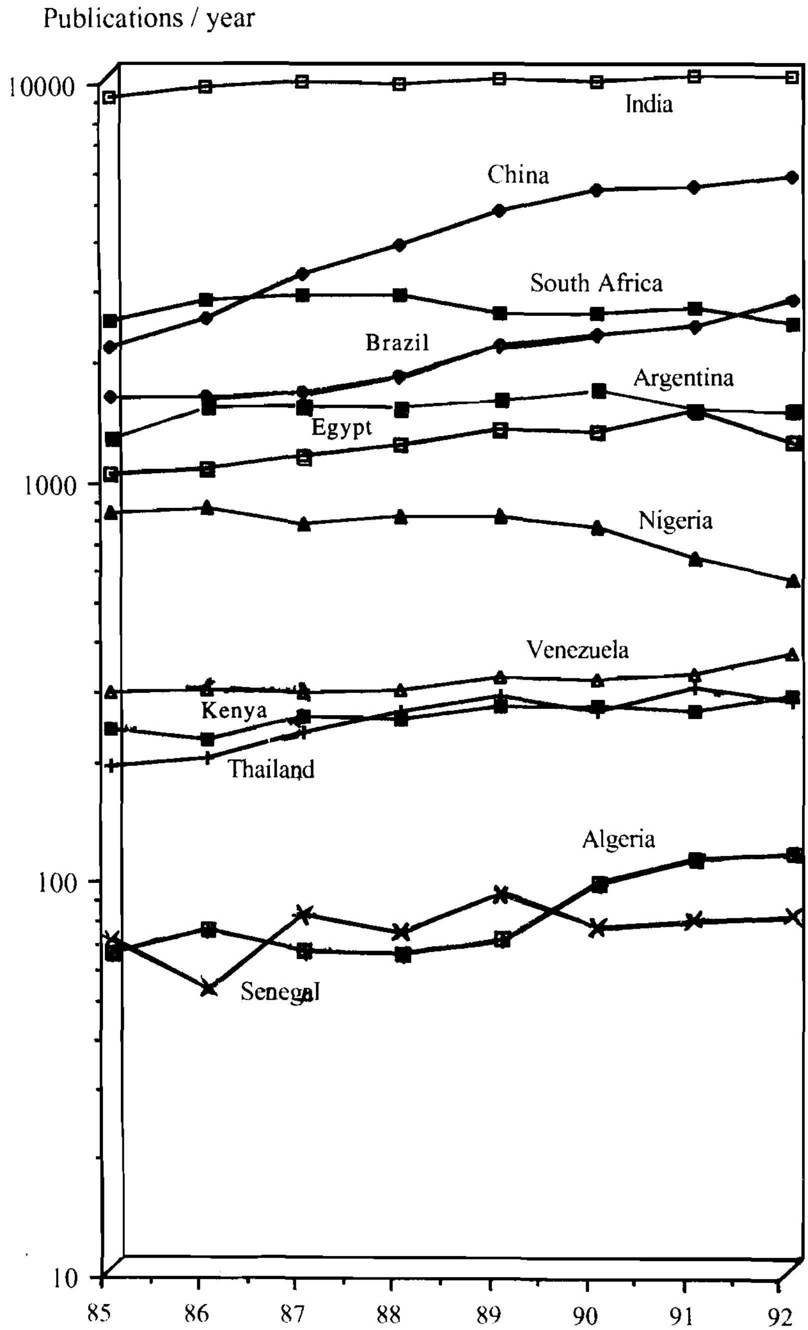
## Relative Position of the Countries under Review in Mainstream Science

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.

## References

**Arvanitis, R.** and **J. Gaillard** (eds.) (1992). *Science Indicators for Developing Countries.* Proceedings of the International Conference on Science Indicators for Developing Countries, Paris, UNESCO, 15–19 October 1990. Paris: ORSTOM, Colloques et Séminaires.

**Basalla, G.** (1967). 'The Spread of Western Science'. *Science*, 156 (3775), 611–22.

**Bhabha, H.J.** (1966). 'Science and the Problems of Development'. *Science*, 4 February 1966, 541–48.

**Browne, J.** (1992). 'A Science of Empire: British Biogeography before Darwin'. *Reviews of History of Science*, XLV(4), 453–75.

**Brundenius, C.** and **B. Göransson** (1993). *New Technology and Global Restructuring: The Third World at a Cross Roads.* London: Taylor and Graham.

**Busch, L.** (1996). 'Le tiers-monde est-il encore necessaire? Biotechnologie, robotique et fin de guerre froide', in R. Waast (ed.). *Les Sciences hors d'occient au XXème siècle, Vol. 1, Les Conferences.* Paris: ORSTOM.

**Chambers, D.W.** (1987). 'Period and Process in Colonial and National Science', in N. Reingold and M. Rothenberg (eds.). *Scientific Colonialism. A Cross-cultural Comparison.* Washington: Smithonian Institution Press.

**Eisemon, T.O., C.H. Davis** and **E.M. Rathgeber** (1985). 'The Transplantation of Science to Anglophone and Francophone Africa'. *Science and Public Policy*, 12(4), 191–202.

**Frame, D.J.** (1985). 'Problems in the Use of Literature-based S&T Indicators in Developing Countries', in H. Morita-Lou (ed.). *Science and Technology Indicators for Development.* Boulder, CO: Westview.

**Frame, D.J., F. Narin** and **M.P. Carpenter** (1977). 'The Distribution of World Science'. *Social Studies of Science*, 7(4), 501–16.

**Gaillard, J.** (1989). 'La science du Tiers Monde est-elle visible?'. *La Recherche*, 20(210), 636–40.

———. (1994). 'North–South Research Partnership: Is Collaboration Possible Between Unequal Partners?'. *Knowledge & Policy*, 7(3), pp. 31–63.

**Garfield, E.** (1983). 'Mapping Science in the Third World'. *Science and Public Policy*, 10(3), June, 112–27.

**Goudineau, Y.** (1990). 'Etre excellent sans être pur: potentiel technologique et pouvoir technocratique à Singapour'. *Cahiers des Sciences Humaines de l'ORSTOM*, 26(3), 379–405.

**Hagenbucher-Sacripanti, F.** (1992). *Santé et rédemption pour les génies au Congo*. Paris: Publisud.

**Headrick, D.R.** (1988). *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850–1940*. New York: Oxford University Press.

**Inkstcr, I.** (1985). 'Scientific Enterprise in Historical Context'. *Social Studies of Science*, 15(4), 677–706.

**International Council for Science Policy Studies** (1990). *Science and Technology in Developing Countries: Strategies for the '90s*. Paris: UNESCO.

**MacLeod, R.** (1982). 'On Visiting the Moving Metropolis: Reflection on the Architecture oof Imperial Science'. *Historical Records of Australian Science*, 5(3), 1–16.

**McClellan II, J.E.** (1992). *Colonisation and Science—Saint Domingue in the Old Regime*. Baltimore: The Johns Hopkins University Press.

**Meyer, J-B.** (1994). 'Dinámica de los grupos de investigadores Colombianos en el exterior'. Paper presented at the International Seminar for Colciencias 25th anniversary 'Dinamica y entorno de los grupos de investigacion', Bogota, 19–20 May.

**Moravcsik, M.J.** (1985). 'Strengthening the Coverage of Third World Science'. Report from the International Task Force for Assessing the Scientific Output from the Third World'. Eugene: Oregon.

**Myrdal, G.** (1968). *Asian Drama: An Inquiry into the Poverty of Nations*. New York: Pantheon Books.

**Nakayama, S.** (1991). 'The Shifting Centers of Sciences'. *Interdisciplinary Science Review*, 16(1), 82–88.

**Needham, J.** (1956). *Science and Civilisation in China, Vols. 1 and 2*. Cambridge: Cambridge University Press.

**Ominami, C.** (1986). *Le Tiers-monde dans la crise*. Paris: La Découverte.

**Orleans, L.A.** (1988). *Chinese Students in America: Policies, Issues and Numbers*. Washington, DC: National Academy Press.

**Osborne, M.A.** (1992). 'The Société Zoologique D'Acclimation and the New French Empire: Science and Political Economy', in P. Petitjean, C. Jami and A.M. Moulin (eds.). *Sciences and Empires: Historical Studies about Scientific Development and European Expansion*. Dodrecht, Netherlands: Kluwer Academic Publishers.

**Pedersen, P.** (1992). 'The New China Syndrome: Delayed Return as a Viable Alternative to the "Brain Drain" Perspective'. Working Paper No. 30. Washington, DC: NAFSA.

**Pereira, P.R.** (1994). 'New Technologies: Opportunities and Threats', in J-J. Salomon, F. Sagasti and C. Sachs-Jeantet (eds.). *The Uncertain Quest: Science, Technology and Development*. Tokyo: The United Nations University Press.

**Petitjean, P.** (1992). 'Scientific Relations as a Crossing of Supplies and Demands of Science: Franco-Brazilian Cases, 1870–1940'. Mimeo. Paris: REHSEIS, CNRS.

**Petitjean, P., C. Jami** and **A.M. Moulin** (eds.) (1992). *Sciences and Empires: Historical Studies about Scientific Development and European Expansion*. Dodrecht, Netherlands: Kluwer Academic Publishers.

**Ravetz, J.R.** (1971). *Scientific Knowledge and its Social Problems*. Oxford: Clarendon Press.

**Ray, P.C.** (1918). *Essays and Discourses*. Madras: G.A. Natesan & Co.

———. (1958). *Autobiography of a Bengali Chemist*. Calcutta: Orient Book Company.

**Reingold, N.** (1991). *Scitnce American Style*. USA: New Brunswick.

**Sachs, I.** (1994). 'The Environmental Challenge', in J-J. Salomon, F. Sagasti and C. Sachs-Jeantet (eds.). *The Uncertain Quest: Science, Technology and Development*. Tokyo: The United Nations University Press.

**Sagasti, F.R.** (1990). 'Science and Technology Policy Research for Development: An Overview and Some Priorities from a Latin American Perspective', in Science and Social Priorities of Science Policy for the 1990s. Proceedings of the Conference sponsored by ICSPS, UNESCO, CAS, Prague, 5–7 June.

**Saldana, J.J.** (1987). 'The Failed Search for Useful Knowledge: Enlightened Scientific and Technological Policies in New Spain', in J.J. Saldana (ed.). *Cross-Cultural Diffusion of Science in Latin America.* Proceedings of Vol. V, Acts of the XVII International Congress of History of Science. Mexico: Cuader Nos de Quipu.

**Salomon, J-J.** (1994). 'Modern Science and Technology', in J-J. Salomon, F. Sagasti and C. Sachs-Jeantet (eds.). *The Uncertain Quest: Science, Technology and Development.* Tokyo: The United Nations University Press.

**Salomon, J-J., F. Sagasti** and **C. Sachs-Jeantet** (eds.) (1994). *The Uncertain Quest: Science, Technology and Development.* Tokyo: The United Nations University Press.

**Salomon, J-J.** and **A. Lebeau** (1988). *L'écrivain public et l'ordinateur: Mirages du développment.* Also published in English as *Mirages of Development.* Boulder, CO: Lynne Rienner.

**Schott, T.** (1991). 'The World Scientific Community: Globality and Globalisation'. *Minerva*, 29, 440–62.

**Schwartzman, S.** (1992). *A Space for Science: The Development of the Scientific Community in Brazil.* University Park, PA: Pennsylvania University Press.

**Serres, M.** (1990). *Le contrat naturel.* Paris: François Burin.

**Shiva, V.** and **J. Bandyopadhyay** (1980). 'The Large and Fragile Community of Scientists in India'. *Minerva*, 18(4), 575–94.

**Stafford, R.A.** (1990). 'Annexing the Landscapes of the Past in British Imperial Geology in the 19th Century', in John M. Mackenzie (ed.). *Imperialism and the Natural World.* Manchester: Manchester University Press.

**UNESCO** (1992). *Science and Technology in Developing Countries: Strategies for the 1990s.* Paris: UNESCO.

**Vessuri, H.** (1994). 'La Academia va al mercado. Un enfoque sociologico de las relaciones de los investigadores academicos con el mundo productivo'. Paper presented at the International Seminar for Colciencias 25th anniversary 'Dinamica y entorno de los grupos de investigacion', Bogota, 19–20 May.

**Villegas, R.** and **G. Cardoza** (1993). 'Latin America'. *World Science Report.* Paris: UNESCO.

**Weber, M.** (1951). *The Religion of China.* Glencoe, Ill.: The Free Press.

———. (1958). *The Protestant Ethic and Spirit of Capitalism.* New York: Charles Scribner's Sons.

**Whitley, R.** (1975). 'Comments of Scientific Activities, their Characteristics and Institutionalisation in Specialities and Research Areas', in K. Knorr, H. Strasser and H.G. Zillan (eds.). *Determinants and Controls of Scientific Developments.* Dordrecht, Holland: Reidel.

———. (1976). 'Umbrella and Polyteistic Scientific Disciplines and their Ethos'. *Social Studies of Science*, 6, 471–97.

———. (1978). 'Types of Sciences, Organisational Strategies and Patterns of Works in Research Laboratories in Different Scientific Fields'. *Social Science Information*, 17(3), 427–47.

**Wolf-Phillips, L.** (1987). 'Why Third World?: Origin, Definition and Usage'. *Third World Quarterly*, 9(4), 1311–27.

**World Bank** (1992). *Global Economic Prospects and the Developing Countries.* Washington, DC: The World Bank.

**Yanchinski, S.** (1987). 'The Newly Industrialized Countries'. *Biofutur*, July–August, p. 34.

# Part 1

# Scientific Communities in Africa

# 2 Sisyphus or the Scientific Communities of Algeria

**Ali El Kenz** and **Roland Waast**

## Epigraph

We finished writing this text in February 1993. At that time, we were both struck very much by the intensive hive of ideas fuelling Algerian researchers. The final note of our historical retrospective was an optimistic one. It reflected the hopes of the engineers, doctors and academicians we had interviewed. Not long afterwards—in March 1993 to be exact—a number of them began getting murdered; many would flee the country fearing for their lives. The Algerian scientific community—along with women—became the victims of the cultural mayhem tearing through the country. An easy target for hired killers, it crumbled before our very eyes within a matter of months. This tragic fate shows the extent to which it had become a rallying light in the darkness of the antagonism gnawing deep into the guts of society. It serves to indicate how fragile the structure of a national scientific community can be in the countries of the South. And yet, we can also see how, by fleeing lands of persecution, it can bounce back and enrich more welcoming regions abroad; regions that are ready to bring such members into the fold of the world scientific community.

---

The story of Algeria's scientific communities is doubly paradoxical. On the one hand, their rapid development came late, without links to any local tradition whatsoever. Also, having emerged on a wave of nationalistic voluntarism, they were first sustained by the state, only to see it shed its support at a delicate point just as a new generation was about to take the helm. They then found themselves stripped of their legitimacy and burdened with the need to re-establish a place in society.

We begin by looking at these developments as a three-stage life cycle: indifference, development, and then, disintegration and possible restructuring. After that, we shall go on to discuss the present-day situation with its fundamental key points: the withdrawal of the state and the ensuing necessary measures to regain recognition, the language conflict, scientist migration and community reproduction problems, opportune niches and accommodating professions, and styles of science and conflicting schools of thought.

## Colonial Legacy

When French colonization swept into Algeria in 1830, the country had its literates, popular knowledge and organized intelligentsia. Yet, it lacked an uninterrupted line linking it back to the tradition of classical Arabic science of the eighth to thirteenth centuries. Algeria had not been an epicentre of it and its methodical practice had long since died out. There followed the building of a colonial science, which could well have been handed on as a legacy to independent Algeria. It too constituted a mishit. Right from the very beginning, the powers of Western science (medicine in particular) set themselves up throughout the country to rally people and modify their view of the world. A deep ideological struggle ensued which, in less than a century, crippled the body of popular knowledge. Science, it must be said, was not just a colonizing tool; it was also fuelled by real curiosity. From 1837 onwards, an official scientific mission spent ten years travelling the length and breadth of the country. It was to lastingly introduce geodesy and geography, 'natural history' and anthropology. It trained and encouraged many local enthusiasts—military men, doctors, settlers and civil servants—who swiftly organized themselves into scientific associations. All of them originally came from the metropolis. A genuine scientific lobby then secured the (contested) creation of a fully working university at Algiers in 1909. It was to remain the only one of its kind in the French Empire. From that point on, scientific activity began to take roots in Algeria: laboratories were set up at the faculty (notably in the natural sciences), specialist reviews burgeoned and the scientist associations came under academic rule.

Meanwhile, Paris based large metropolitan institutions such as le Muséum d'Histoire Naturelle (MHN), les Instituts Pasteur and l'Académie des Sciences started taking a strategic interest in establishing networking ties and observatories. MHN was given a new lease of life when it persuaded the ministries to try out its new 'acclimatization' theories in colonial 'botanical gardens'—the best and most illustrious of them was that of Algiers established in 1832. In 1880, in the name of the 'universal science watch', the prestigious Académie des Sciences established an astronomical and geophysical observatory in Algeria under its own seal and control. The followers of Pasteur, who were promoting a new school of thought,[1] needed to prove their worth and build up prestige in peripheral branches. In 1894, an overseas branch of the Institut Pasteur was established in Algiers to join the list of those set up at the same period in other colonies. These newly installed establishments provided a number of great scientists with theatres of operations from which many important discoveries were to emerge. Some would be awarded the Nobel Prize, e.g., the first parasitology work on malaria.[2]

In the aftermath of the First World War, a change in the colonial doctrines produced 'agricultural experimentation stations'.[3] Into these forerunners of the agricultural research centres, agricultural engineers introduced both genetics (a fringe discipline in metropolitan universities and better known to them) and 'development' concerns. Botany and zoology, for groundwork rather than utilitarian purposes, were either taken under the wing of enthusiasts or went into decline, and with them went the botanical gardens. Following the Second World War, a further change in the hierarchy of politico-economic concerns and scientific doctrines led to a final wave of institution-building. There were three sides to this: respect for the techno-sciences prevailed, the foundations of 'autonomy' were laid in the colonies and interest grew in the Sahara (French atomic test site). A Centre de Recherches Nucléaires and Centre Pierre et Marie Curie (involved in radiology, haematology and nuclear medicine) were set up; and the Centre de Géophysique was consolidated as was, among others, the Centre de Recherches Sahariennes.

However, towards the late 1950s the Algerian War of Liberation was brewing. Looking back at the earlier episodes gives us a list of the institutions the independent government would inherit. Yet, many of the scientific institutions established had not been fully institutionalized, in the sense that they would not be able to sustain themselves with local resources, both human and material, in the event of a political upheaval. They had been operating neither as educational incubators nor as anchorage points for new schools of thought, working to carve out a forthcoming, local style of science. In the event of independence, their premises and equipment would be handed down only as empty shells since most of the researchers who had been running them were French and would leave the country with no intention of ever returning. The institutions had not prepared a relief team. The few 'Muslim' students educated at the university were mainly engaged in professions rather than research, e.g., chemists, doctors and lawyers. It was in the high schools and teacher training colleges that an active exhange of ideas and a taste for science had only recently begun. Another problem was that many Algerian graduates were abroad in the diaspora and being trained in very different surroundings. As for the independent government, being absorbed in emergency measures, it would consistently leave the scientific institutions it inherited aside for some time to come.

## Science and Independence

### The First Period—1962–1974: Indifference

The independence of Algeria in July 1962 was to release the country from a colonial rule that had become intolerable for both the working classes, subjected to survival under the settler's yoke, and the delicately poised elites—Arabic speaking or 'Frenchified'—who had successfully avoided being bulldozed into impoverishment. Colonization here had, unlike in Tunisia or Morocco, been total, profound and radical. This left the Algerian people no alternative other than to achieve independence through a corresponding reaction of the same order—total, profound and radical. Independence came in a violent clash between the two communities. Beyond this, it was a rupture in the fullest sense of the term: the French beat a mass and disorderly retreat, leaving the Algerians to manage the economic and administrative machinery and technological infrastructure—a mammoth task for which they had neither the necessary experience nor ability. All analyses show that in Algeria, the colonial political system had doggedly pursued a tough line in containment strategy. Very few Algerians were able to reach even middle management levels in the administration, economy or education and, moreover, very few were qualified to acquire the skills such functions demanded.[4]

The nationalist leaders had clearly been conscious of this dimension for some time. During the early 1950s, up until the armed conflict broke out in 1954, they urged students to push their studies further into subjects that would be 'useful' later on. The amount of special attention granted to S&T is remarkable. Its measure can be gauged by the often decisive role that student associations such as AEMAN, UGEMA, and UNEA[5] would play in the nationalist movement: far more important, to begin with at least, than that of any trade unionist, worker or peasant organizations. The UGEMA, which had been set up in 1955 and was totally aligned with the Front de Libération Nationale (FLN)'s political agenda, thus encouraged the most politically aware students to join the resistance movements after the all-out student's strike of 1956–1957. They were to form an 'inner circle'[6] from which the elements of independent Algeria's first S&T policy would gradually be constituted. The first initiatives launched by the Tunis or Cairo branches of the GPRA[7] were already revelatory of the 'inner circle's' fundamental 'values': the use of international aid to finance a large number of students in their S&T and medicine-related studies rather than the social sciences such as law, economics or the arts; and the dispatching of trainees into a very wide range of countries, irrespective of their prevailing political systems (socialist or capitalist) and the cultural area to which they belonged (the Arab world or not). The essential goal was that they should gain an education and acquire competence in S&T which they would use to take over a European techno-structure, otherwise destined to vanish after independence.[8]

Such a pragmatic approach was undoubtedly adopted because of the needs of the time. The fact that the colonial system had trained such few Algerian technicians and scientists meant that there was now a gap to be quickly bridged so as to minimize the hardships of managing the post-independence period. It nevertheless remains a sign of the eclecticism of Algerian nationalism in this domain, contributing as we shall see later to the founding of an essentially 'positivist' approach to S&T, and whose corrupting and destructive effects would only be felt years later.

For the time being in 1961 preparations were made with all due haste. Independence was imminent and the French were leaving en masse. The country's economic and administrative machinery needed to be kept going and this concerned, among others, the complex and now vacated scientific and technical facilities that the Algerians had previously little frequented. The first graduates began returning to the country, but there were barely enough of them to take over the major posts of responsibility, when they were not being asked to deal with immediately more pressing matters in the political administration.

Algeria was counting on the quite generous amounts of international aid it was then receiving (in the 1960s and for another few years to come). Arab countries, especially Egypt, were dispatching teachers in thousands in order to provide a schooling that would hopefully be open to one and all in a democratic way. The Accords d'Evian agreement, which outlined relations between independent Algeria and its former metropolis, made possible technical assistance in S&T for the following decade. So the essence of scientific and technological cooperation was thus provided by the French state and would, for a number of years, serve to fill the gap left by the abrupt colonial 'vacuum'.[9] Up until the early 1970s, the new state of Algeria however managed the inherited institutions of science just to avoid the situation of leaving them empty. On-the-ground Algerian researchers received little encouragement or support in their endeavours to capitalize on foreign technical assistance and in the furtherance of their work. In all, almost four hundred researchers (half of them foreigners—chiefly French) were distributed in three main sectors:

- The institutions of the Office de Coopération Scientifique (OCS—the Science and Technology Cooperation Body) with forty-two Algerian and fifty-five French researchers; of whom twenty-eight and thirty-one respectively worked at the Institut d'Etudes Nucléaires (IEN—Nuclear Studies Institute).
- The research institutions of the University of Algiers with seventy-eight teachers and ninety-five researchers (plus a further 140 PhD students

acting as 'assistant researchers', mainly working in the physics, chemistry, earth sciences and biology departments.

- The Faculty of Medicine and the Institut Pasteur with forty or so researchers, half of them foreigners.

The remainder were dispersed in a few agromony stations, small social science units—anthropology research centres in particular—and the faculties of law and economics. There were virtually none in industry, mining, hydraulics, energy, civil engineering or architecture.[10]

From the discussion of the first decade of Algerian independence, it is visibly difficult to talk about a *national* scientific community with solid traditions in research and supported by a stable network of research groups, libraries, laboratories, journals, etc. Also, the plans or views for a national science policy were still very far from the mind of the new state leadership. The emergencies lay elsewhere and nobody talked about scientific research. It was nonetheless a decisive decade in more ways than one. A national research 'experiment', no matter how minimal it may have been, was launched. This would provide the first steps towards defining a totally 'original–local' profile for the formation of an Algerian community of scientists. The first original feature was its 'nationalistic' tone. As mentioned earlier, this dates back to when the nationalist movement itself was formed. Political nationalism not being enough, however, the community now had to take up concrete research activity with all the commitment of a new 'cause'. What better, therefore, than to undertake 'useful' research, which at that time meant applied research. Applied science, the future ethical and political creed of this emerging community, was to be upheld by a relatively inexperienced body of practitioners who lacked ad hoc equipped research centres: colonial science had not provided any such centres for industrial sciences. This creed met the objectives of the new state leaders who were trying to make *development* the central axis of the national policy. Both scientists and state leaders alike were aiming at almost exactly the same goals. While the state was launching into a bold programme of industrial investment and the nationalization of 'foreign' property, scientists were hard at work developing research and technology, public health and social sciences—development areas which were unanimously seen as constituting the 'natural' cultural and scientific milieu of the project for a new society.

That social project was basically the work of a state conceived as a history-making force designed to provide a general framework for the evolution of a new society. Let us not forget that at that time many countries in different parts of the Third World were adapting to the pattern of state 'socialism' in varying ways. The Algerian version was an exemplary and pioneering model. After the nationalization of the hydrocarbon industry in 1971 and the state takeover of gas and petrol resources, state control could no longer be considered as an ideology nor as just the political spin-off of a military coup d'état (in this case, that of 19 June 1965). It became an organic, economic and financial reality that none could escape, not least the fragile, fledlging 'community of science', which, like the rest of society, would eventually come to realize that state-controlled institutions were the only ones holding the keys to the future of research.

Therefore, in this stage of formation, the Algerian scientific community came to be characterized by its nationalism, developmentalism and state dominance. Already, though a certain 'style' was emerging, it came from both the recklessness of youth and a dogged strength of convictions that could not be tempered by elders or experience, since there were none. We also notice the openness to 'world science', a by-product of its members' scientific training, paradoxically coupled with their strong 'resistance to foreigners'—the fruit of their political background. During this early stage of life, the embryonic Algerian scientific community proved it had a well and truly 'pioneering' spirit. Due to its weak anchorage in the new society and its inexperience, however, the community looked to the state to take the initiative—perhaps too exclusively so. It thus put all of its energy into supporting the state's establishing of the Office National de la Recherche Scientifique (ONRS—National Scientific Research Bureau), of which it was to wear its 'uniform' and which, as any 'uniform' can, was to eventually turn into a 'straightjacket'.

## The Second Period—1974–1983: The Nationalist Upsurge

The state only started taking an interest in S&T quite late. Power changed hands in 1965. From 1966, mining and then hydrocarbon extraction were nationalized, giving the government the means with which to finance an ambitious programme of national industrialization. Huge state factories such as iron and steel and petrochemicals among others, were built. Worker communities sprang up amidst the ruins of a rural society already uprooted by the War of Liberation. In the space of a decade, half the population was urbanized. The top priority business of the day was the forging of a strong nation state. Other initiatives fell to the wayside due to differences between two long-standing rival factions of the nationalist movement: one supporting the belief that the road to freedom lay in restoring authenticity—with hardly a thought for the future; the other holding that mastering the elements was the key—'making' should thus take precedence over tending to cultural roots. The latter, and at that time the more dominant of the two, rallied its followers under the banner of 'production'. The former stood to promote the Arabic 'language' and reserved for itself the right to control the education system. 'Technicists' had to transgress the divide to move into the world of teaching. This they did in 1970, encroaching on the area of higher education.

The resulting powerful reforms emerged on a razor's edge and in the face of the 'culturalist' faction's hostile opposition to 'industrialism'. These reforms marked a definite turning point, both for the university and the area we are concentrating on here—the research system. It was a critical juncture, in that it swiftly brought about profound institutional change; but, more importantly, it led to the rallying of the scientific community's future helmsmen and to the making of the cognitive choices that would direct the style of Algerian research for some time to come.

First of all, major changes took place at the universities. Degree courses were released from the French teaching structures. Their content was updated with a significant part being devoted to practical training. Student places and teaching posts were increased in number. Faculties (especially those of the sciences and medicine) were enhanced, equipped and raised to a place of greater importance. New faculties appeared in the provinces and the capital (Table 2.1).

TABLE 2.1
**Growth of Number of Students and Degrees in Algerian Universities, 1857–1990**

| *Years* | *No. of Universities* | *No. of Students* | *No. of Teachers* | *No. of Degrees*** |
|---|---|---|---|---|
| 1857–1905 | 1 | 600* | 30* | 7 |
| 1906–1955 | 1 | 2000* | 300* | 50 |
| 1962 | 1 | 2700 | 300 | 180 |
| 1969 | 1 | 6000 | 700 | 650 |
| 1976 | 3 | 36000 | 5000 | 4700 |
| 1980 | 6 | 51000 | 8000 | 6100 |
| 1985 | – | 100000 | 10500 | 11500 |
| 1990 | 16 | 170000 | 12000 | 16000 |

For the periods 1857–1905 and 1906 and 1955, degrees are those delivered to Muslim students only.
The number of students, teachers and degrees are averages per year.
* Approximate figures.
** Per year.

Meanwhile, new establishments of higher education, outside the universities and under the supervision of the technical ministries were busy training engineers and advanced technicians in areas where they were most needed. In the *grandes écoles* and institutes of technology, a significant amount of time was devoted to field training and practitioners began moving into the ranks of the teaching body (Table 2.2).

TABLE 2.2
Growth of Different Higher Education Sectors in Algeria, 1970–90

| | *Number of Students* | | | *Number of Degrees Awarded (BSc and above)* | | |
|---|---|---|---|---|---|---|
| Years | 1972 | 1980 | 1987 | 1972 | 1980 | 1987 |
| University | 18000 | 51000 | 145000 | 3000 | 6100 | 11500 |
| Non-university* | 2000 | 15000 | 47000 | 500 | 3500 | 16000 |
| PhD Candidates in Foreign Countries | 1300 | 2500 | 6000 | – | – | – |

* 'Ecoles' and Institutes of Technology.

It was not long before official attention turned to focus, for the first time ever, on research. The operation was prepared in 1972 by the National Assizes on a mandate from the Ministry for Higher Education. Following the public debate, it was decided to revise the Franco–Algerian cooperation agreement (which left the institutions handed on at independence in the care of the former metropolis), and to institute the ONRS, which was led by a scientist. This well-funded inter-ministerial body was assigned to develop human scientific potential, organize efforts within the framework of research programmes, equip and guide university laboratories, manage research centres which it either set up itself or had taken over, and counsel those remaining under the supervision of the technical ministries.

On a deeper level, the new options rallied a small coherent group of professionals, who then became the founding generation of Algerian research. The job of drawing up the reforms (of the universities and then of research) had been delegated to small groups of specialists who would later become the 'grass-roots players'. They may well have been close to the nationalist 'inner circle', but were also eminent figures in their respective fields. All were enlisted during a genuine 'head hunt': not just in Algeria but in the diaspora too.

Hence, a biochemist, for example, trained in Sweden (where he had been working with a Nobel Prize winner), or a virologist trained in the USSR and working in the USA, or a chemist occupying a post at the French CNRS, and so on, returned to Algeria. These people knew that they would find working conditions to satisfy the prerequisites that they themselves had helped to define. Other members of the small groups of specialists were drawn from among those already working on the spot to overhaul Algerian science, such as in the environmental and mathematical fields. Others were not researchers, their preferences having up to now lain in teaching. Almost all had a common advanced level of commitment (on ethical grounds sometimes as much as political) as well as a first taste of life experienced during studious, adventurous and fruitful times spent in a number of countries abroad following the student's strike called by the UGEMA in 1956. Mutual respect among peers brought them to agree to the demand for quality. Perhaps on the insistence of professionals from the diaspora, they pulled together to make research duty an obligatory part of being a university teacher, and they began by imposing that duty on themselves first. 'No university worthy of the name can do without it', said a senior professor, who has since become one of the most high profile researchers in haematology in the country. This rallying of young masters discovering the field of research and then setting out to explore it was of enduring scope. They were to make a vocation of it and never give up, come what may.

The other far-reaching feature was in the choice of the initial research subjects. There followed a long period of commitment to master them. A good number of PhDs were urged to take stock of the field, so that the equipment gathered and the abilities of tutors could be most profitably exploited. The stockpiling of abilities would take place upon these first foundation stones and the 'layout of the land', in terms of the strong points of Algerian research, was to be shaped by it. The prevailing selection strategy was coloured by nationalistic tones. It used the existing institutions (the colonial 'bequest') for support of course, and reflected the specific and sometimes haphazard areas of abilities of the young masters. This double historical 'stroke of luck' only partly explains the cognitive orientation. The needs of the state planner at that time were important ingredients too. Though they were not always accepted as presented, the scientists transposed them into their various disciplines—nonetheless keeping true to their original spirit.

The ONRS subtly declined to dictate study subjects at the outset. It did not begin by trying to lay down the law to a still virtual 'body of researchers'. On the contrary, enjoying the full trust of the state, it swiftly created a multitude of vocations—above all at the universities. The goal was to produce 'pools' of scientists and the sorting would come later. This is not to say the initiative was disorganized. On the contrary, it unfolded within the framework of teams which were structured, working on programmes and gathered in university laboratories (or ONRS well-equipped research centres). Contract work (with ministries and public companies) was encouraged, but attracted few partners. Individual research projects, allowed at first, gradually had to fall in line with these rules. The requirements introduced essentially concerned scientific output such as theses, articles and symposia papers. There appeared a flurry of national journals linked to research centres, schools and laboratories.[11] Scientific meetings grew ever more numerous. Scientific commissions were constituted to assess the new projects submitted for funding in terms of their feasibility (intellectual and material), originality and national interest (immediate or forthcoming).

Candidates for promotion within the university system would hence be required to satisfy conditions of scientific output.

International cooperation efforts were made in some important fields of science. As the founding members of various laboratories had been trained in such a wide variety of areas in different places, they were able to call on a diversified range of partner countries. Diversification also grew to some extent as some specialist groups in areas such as ecology, mathematics and nuclear physics gradually gained in personality and renown. Evidence can be seen in the range of different languages in which Algerian work was being published, the rate of international co-authoring and the growth of networks of collaboration. In Algeria, this was more of a fact of life in the experimental than in the social sciences (which too were concerned with trying to steer clear of a possible foreign cultural imperialism).

Although ONRS was originally instituted simply to supplement the universities, in a matter of a few years it was to successfully turn research into a sector in its own right, with its own anchorage points and relative autonomy. The first laboratories seemed to outgrow their early 'sketchiness' and settled into a routine of sound work. Sure enough, the rapid expansion had not given the younger generation time to fully assimilate norms and professional ideals. Evidence can be seen in the number of applicants who only produced just a single piece of work (thesis or paper, undertaken on trial or solely for their degree). But the overall picture appears to be on the positive side, for instance in the year 1983, as can be seen in the international bibliographical database lists relating to 'visible national science' (see Table 2.3) and in ONRS's own activity reports (see Table 2.4).

TABLE 2.3
**Publication Output, 1980–90**

| *Year* | *Publication Output* |
|---|---|
| 1980 | 127 |
| 1983 | 208 |
| 1986 | 110 |
| 1990 | 106 |

**Source**: PASCAL database.

TABLE 2.4
**Annual Averages of Publications Indexed by ONRS, PASCAL and ISI**

| *Institute* | *Publications Indexed* |
|---|---|
| ONRS (Algérie) 1975–83 | 128 + 177 communications in conferences |
| Base PASCAL (France) 1981–86 | 118 |
| Base ISI (USA) 1981–86 | 80 |

However, it was at that very moment that ONRS was to be hit by a crushing onslaught. Algerian research would consequently be at great pains to recover; the episode nevertheless gave a clearer perception of the fragility and distinctive features of the formerly built structure.

The universities' desire for research was greater than that of the production sector. Industrialists had not set their sights on such advanced sectors which, in Brazil for example, were to lead the youthful computer or aeronautics firms to signing a significant number of study contracts with colleges and faculties, then to subsequently absorb those university laboratory partners into their own research centres (Botelho, 1995). Neither had the Algerian state taken the initiative to organize scientific research prefiguring the technologies of the future, unlike in East or South-east Asia, for example.[12]

The big Algerian companies were quite slow in setting up engineering units, and those with their own research centres (chiefly iron and steel, petrochemicals and mining) were rare. Innovation for them took second place and they were more satisfied with ensuring that the factories installed were working to full capacity. Their felt need was for production engineers and in some cases they were anxious to ensure that the institutes of technology did not cultivate the spread of research to the detriment of in-the-field training. The technical ministries had retained their supervision of many institutes of research. They tended to consider most of these as service laboratories mainly devoted, in agriculture for example, to natural resource surveys or quality control. The technical ministries distrusted the ONRS programmes under which coordinated work projects were carried out. They feared their staff might be deflected from the production tasks which they saw to be more important.

It may be reiterated that at the time of independence, research in Algeria had been without tradition, followers or mandate. It had to build up its own legitimacy, activity by activity. Each activity had to create its own sense of meaning, within the terms of one of the 'liberating' schools of thought leading social initiatives. Research did not exactly belong to the 'production' school and defended itself against it in its efforts to win autonomy. Nor did it feel itself to be any closer to the doctrines of the 'language' school, due to its lack of interest in the innovation and quality of the contents. The overall recognition that was granted during the lifetime of ONRS came due to state support. One of the dangers was that it might be sucked into becoming a 'state science' and become afflicted by its flaws. Another was that it could easily perish with a change of government. ONRS managed to avoid the first in spite of its code of ethics being one of a national, development-oriented science. It was saved by its promoter's strategy of subject selection, though not in every discipline (we shall come back to this later on). But the latter pitfall claimed its own victims.

During this period, the highest degree of recognition was awarded to the 'historic chiefs' of the War of Liberation, then to the Army, and then to the builders and upholders of the state, that is, the bureaucracies which were the most exclusive, prestigious and privileged of all categories. The major players of the two main initiating factions (the 'industrialists' and 'educators') only figured after these privileged categories. They were trying to build up their eminence and form themselves into a 'corps' of professionals. Researchers actually belonged to none of these groupings. They only gained recognition by virtue of their activity contingent. When the state changed course, the lack of legitimate social allies would prove fatal.

## The Third Period—1983 to the Present: Dismemberment

Of the three decades in its short history, the last—the 1980s—can be said to have been the hardest and the most testing for the Algerian scientific community. As seen earlier, the first had in fact been one of foundation, exploration and laying the first steps. It had unfurled in the general mood of the time—the building of a modern society freed from colonialism, open to progress and community spirit. The satisfaction enjoyed by the cells of scientists who had been working at that time was twofold. First, despite being 'assisted' by foreign cooperators they were nonetheless gaining status levels from which they had previously been practically barred and were becoming 'seniors' in their fields of research. Second, they were aware of the part their work played in the common *oeuvre* and felt they were in some way 'activists' for the general cause. The task they were accomplishing had all the qualities of a 'mission'.

The second period can be said to have started when ONRS was set up in 1974, continuing up to its dissolution in 1983. In it, the scientific community was institutionalized and began working within organized frameworks of solid goals, precise deadlines and cost assessments. Unlike the first period, where researchers were somewhat left to their own devices, 'organization' had now become the overriding operative word behind the action. Since all the impetus came from the state-controlled institutions, the researchers' 'missionary' robes were progressively exchanged for those of 'civil servant', and militant commitment gave way to routine.

Yet, hardly had the community settled down, with the first networks established and the first results coming in for evaluation, everything in terms of both approach and style had to be changed from top to bottom. One or two points of history may be made here for a clearer understanding of the new situation. Indeed, Algeria's entire political arena underwent full-scale changes after the death of President Boumedienne. From the beginning of 1980, his successor, Chadli Benjedid, arranged an extraordinary congress for the ruling FLN—the only party in existence. It adopted another, quite different political stance. The new politics were more attuned to the 'spirit of the times'—Thatcherism, 'death of ideology' and free enterprise were the rage—and tabled extensive reforms to bring about a total shake-up of the country's economic, social and political scene. Some of the major changes that were brought in during this period are as follows:

- The rapid and massive-scale industrialization programme was put on ice and attention diverted to the sectors of agriculture, housing, roads and other technical infrastructure.
- The public sector (80 per cent of the national economy) underwent in-depth restructuring. The big companies often covering whole branches of industrial activity (SONATRACH—petrol and gas; SNS—iron and steel, metallurgy; SONACOME—mechanical engineering), were split up into smaller units specific to technological sub-sectors or regions. So there were now over a hundred medium-sized companies and around two hundred units of more modest dimensions.
- The state progressively withdrew from most sectors, preferring partnerships with new 'social players', particularly private initiatives and foreign investments.
- Progress towards a free economy shifted up a gear when petrol prices plummeted in 1986, as petrol accounted for 90 per cent of Algeria's foreign currency earnings.

It was in these circumstances, amid the withdrawal of state-owned institutions, that ONRS was dissolved in 1983. The state retained direct control, but over a 'handful' of centres including the Centre des Energies Nouvelles (CEN—Centre for New Energies) which was chiefly nuclear. The scientific community then found itself in utter disarray, not without cause. Extreme institutional instability took hold in the breach left by the disappearance of ONRS. The following year, in 1984, the Commissariat à la Recherche Scientifique et Technique (CRST—Science and Technology Research Board) under the authority of the head of the government was set up. A few months later it was replaced by the Haut Commissariat à la Recherche (HCR—High Commission for Research), this time answerable to the Presidency of the Republic. The HCR in turn made way for a delegated ministry which was to be headed by a junior minister.

With the loss of the 'mother ship' of national research, scientists would thus also lose the main, if not sole, source of funding for their work. In the ten-year period 1979–1989, the annual per capita researcher grant dropped from DA122,000 to DA35,000 (the dinar meanwhile having been devalued), while the number of researchers dramatically increased from 800 to 3,000. That was not all. With the disappearance of its 'institutional research space', the young scientific community also lost its socio-professional status, which had been of great use in such an extremely socialist state society in the habit of working in corporations or on 'orders'. Researchers were now isolated in their various 'home establishments', such as universities, hospitals and research centres. There were still very few full-time researchers, gradually losing their collective identity and hence their power to lobby politicians and influence decision making. They found themselves suddenly stranded in a hostile wilderness.

The other backers with whom they had begun establishing closed contacts, were in turn crippled by the corrosive effects of the state reforms. The big industrial companies being dismantled, the first elements of scientific and technical research that they had been putting together were consequently left high and dry. Funding allocated to research dwindled here, sometimes even drying up altogether (Table 2.5). Meanwhile, the restructuring of production cast a cloud of confusion over all the paths and networks that had begun being woven amongst the companies, and between them and the research institutions. Only the largest industrial establishments (SONATRACH in petrol research; SIDER in iron and steel; SONAREM in mining) continued to maintain their research units. Everywhere else, budgetary cut-backs along with restructuring plans ruthlessly wiped out the funds allocated to research. Scientists could not obtain any considerable support from the new private establishments, as they were still far too weak to finance such activities. The new policy reforms thus delivered a severe blow to university and industrial research.

TABLE 2.5
**Research Budgets in the University Sector, 1976–90**

| *Years* | *1976–82* | *1983–89* | *1990–94* |
|---|---|---|---|
| Capital Investments* | 90000 | 50000 | 80000 |
| Recurring Expenditures* | 100000 | – | – |
| No. of Researchers | 900 | 2600 | 3600 |
| Mean Budget by Researcher* | 100 | 35 | 35 |

* In thousand DA; 1DA = 1FF in 1979. 1DA = 0.15F or approx. US $0.025 in 1989.

The university scientific community was the worst hit. While it had been organizing and conducting its research work according to the S&T 'options' solemnly adopted by all the various successive post-independence political regimes, the education system had been on another path.[13] It had been trying to salvage a cultural heritage profoundly denaturalized at the hands of the colonialists: above all the Arabic language and those (chiefly religious) identity values representing the main elements of the 'fundamental nature of Algeria'. The two logics—of culture and identity for the education system, and of development and S&T for the 'techno-structure' to which the researcher community belonged—had been simultaneously working in two separate, parallel spheres; the former in the schools and the latter in business and the universities. Yet at that time, the first school-leavers were just entering university and on the basis of their cultural values they were attempting to challenge the leadership of their elders.

Thirty years on from independence, therefore, the battle of the 'M' (Muslim)—of the glory days of the UGEMA—is once again flaring up with just as much vigour, as if the identity question is simply coming out of suspended animation. This time, though, the 'M' is no longer being brandished by the elders, but by a youth filled with reproach for their predecessor's postitivism and scornful of the values that come of it. Having been shamefully 'dumped' by a retreating state and being, for the moment, useless to a steadily diluting industrial system, university scientists are being challenged within the very walls of their own 'stronghold' by their own students. This has been enough to speed up a general process of withdrawal in a wide variety of forms:

DEPARTURES ABROAD: The classic 'brain drain' syndrome common to a majority of the Third World countries, which have heavily invested in higher technical education–training but which have not managed to set up a productive system making jobs available to new graduates, has engulfed Algeria now. In Algeria's case, second generation graduates are the ones leaving rather than their seniors. Although many are doing so, we do not as yet know the exact extent of the exodus. Most are from the technological and engineering sciences and head especially towards the USA, Canada, France and Germany. Departure is often final, since those leaving are still young enough to begin a new life 'over there'.[14] The hardest hit institutions are the major universities of science—Bab-Ezzour in Algiers, Es Senia in Oran, the University of Annaba, and the Boumerdes and Arzew centres of technology.

RETREAT INTO TEACHING WORK: This mainly affects the new provincial universities, whose difficult environment and incompetent bureaucracy discourage any effort to establish a team or network, or organize symposia. On a national level, social sciences and the arts are the hardest hit.[15]

SUBSIDING VOCATIONS: Probably this is the most important and disturbing phenomenon. In every discipline and academic establishment there are dwindling numbers of young researchers. Working conditions are deteriorating and the development of results has been reduced virtually to zero, while career plans are slow to see the light of day with the postgraduate system so inefficient and 'Malthusian'. Thus, it takes an assistant several years to become an MSc, and a further ten or so to obtain a PhD. Though the universities are the main loci of research, only around 2,000 teachers are involved in research out of the total registered 7,500. As such, research activity is becoming of far lesser interest to the community, which is otherwise also not very large. So the scientific community is, therefore, growing old, without being aware of it. The 'niche' it had built to house the best in human activity has proved itself too fragile to withstand the onslaught of an unpredictably complex political, economic and cultural environment. Although the third period of Algeria's brief history has been more ardous than expected, it is now in a new phase of apprenticeship and fresh procedures are already emerging. They may be less sure-footed than those of the 'golden age', but they are better aware of the complexity of things and more cautious of the fragility of 'all things institutional'. Scientific researcher associations are growing in number, now independent of little or untrusted state initiatives. They regroup research professionals (sometimes), university teachers (often) and associate particularly public sector company chiefs in their actions. In the majority of cases, their goal is to meet, exchange opinions and measure their strengths. The approaches are new, less bureaucratic, more directly linked to concrete areas of research and concentrated on the conditions for its revival. In these tempestuous times, which have shaken every certainty and profoundly damaged the national community of S&T, a new 'style' may be taking shape. And who knows, if it manages to flower, its bloom could mark the end of this gloomy period.[16]

## The Current Situation[17]

Having, in the space of thirty years, known the void of indifference, an intense, brief gain of autonomy under the aegis of the state, its loss and the ensuing endeavours to achieve fresh legitimacy, where does Algerian science stand today? We shall look at four of the problems it faces: institutional strategies, the reproduction of its communities, its sustaining 'niches' and its cognitive styles of science.

INSTITUTIONAL STRATEGIES: Algerian research was built parallel to the state, received its support and then had it more or less severed. The ordeal tested the mettle of various 'state sciences' and vocations, revealing whether they had staying power or not. Some genuine researchers would turn expatriate in the process. As for the institutions, they adopted variable strategies as a means to survive. Several types of situation can be seen.

The most able laboratories, often the first forged and now resistant kernels, have remained *at the university*. This is due to the doggedness of their members (including their founders) and the determination of a handful of people at the Ministry for Higher Education. They have struggled upstream to maintain the institutional frameworks for healthy scientific life (commissions of specialists, quality requirements and budgetary aid—though at a minimum, yet adapted and distributed directly to the producers). Today, these laboratories are endeavouring to tie contractual bonds with big companies, and they are striving to get their managers interested in postgraduate training and discipline-specific associations focusing on matters of industrial innovation in chemistry, computer sciences, mechanical engineering, etc. Medicine is not as much linked with a 'parent' industry.[18] In the engineering schools (and institutes of technology), research is making an unprecedented comeback as these schools adopt a professional strategy for teaching PhDs.[19]

The research centres are, for the most part, much less productive. Looking for protection, they had put themselves entirely in the hands of the technical ministries after ONRS was dissolved. Significantly, they showed their alliance by ousting the university academicians who were running or wanted to work in these institutions, e.g., the Centre de Recherche en Océanographie (now the Institut Supérieur Maritime—ISMA) or the Centre de Recherches Nucléaires (Nuclear Research Centre) under the aegis of CEN. Meanwhile, the Ministry of Agriculture has barred university and agronomy school teachers from its research system, which is now split up into a whole host of product-specialized service stations. Allegiance has, however, earned these centres premises, equipment and a few posts for young researchers. But no original scientific programmes seem to have come of the fresh start. Their part of the bargain is that, when asked, they take on incidental and changeable 'applied' problems which can often be mundane and as such eventually dry up their imagination. The fact remains that these are among the best equipped places and that in several important disciplines (oceanography, agriculture, nuclear physics, etc.) there has been a de facto divorce between the research tools and those that know best how to use them. Some centres have obviously been affected by this, though less so, depending on the degree of change they have accepted in the hierarchy of their missions. One such example could be the Institut Pasteur, formerly known for its basic research before its epidemiology watch (a role nonetheless played with imagination) and vaccine production. The order of priorities has changed, and the Institute journal is having trouble appearing and is apparently being held in lower esteem.

The industrial company research units have been forcibly pushed to innovate. Since the dismembering of the consortia upon which they depended, they have been turned into independent firms or made to find a 'market'. Some of them have fallen by the wayside in the effort. Others have been torn by internal debate. The researchers have been urged to actually change their careers and even their value systems. A few though have managed to diversify their 'clientele' and increase the number of subjects to which their know-how is applied. One such institution is, for instance, the SIDER research unit which figures in the UNESCO commissioned survey of successful institutions in Arab countries.

Many researchers fled from the research centres and firms during the turmoil to the universities. Others set up their own research companies or consultancies. Such developments, however, are too fresh for us to report on; and they remain personal ventures. If there is a restoration, it is occurring rather within the framework of scientific and discipline-specific associations or associations producing studies under contract. The latter form is promising, especially in the social sciences and in certain technological areas. The fact remains that it is hard to see how medicine or physics can work in such a fashion.

On top of all this, researchers and entire disciplines have vanished without a trace, as they were too tightly controlled by a 'state science' cultivating expressly dictated subjects or paradigms. Although the Algerian scientific community may appear to have entered an age of associations and specialist circles, replacing the institutions whose imagination has run dry seems nearly impossible. The small community that exists now still faces a dual problem: it needs a project to revive it and is having trouble simply reproducing.

THE REPRODUCTION OF SCIENTIFIC COMMUNITIES: Now that it is time to hand over the helm, the charismatic founders are paradoxically finding it more difficult than ever to pass on their leadership. The process is handicapped by the departure of the early followers and by the discord between the older and younger generations over the language used at work. The project to establish a new system of higher education (and then national research) had managed to bring in a good deal of expatriate talent back into the country in the 1970s. But the new course has forced many noteworthy second generation scientists out into the diaspora: those who had been called on to succeed the older masters and had long been preparing for it in major laboratories, and those already starting to work their way into provincial universities. The phenomenon has been accentuated by a change in the balance of power between the country's 'liberating' paradigms and the clear rise of political fundamentalism. It prevails not only at the universities but also in the top levels of the medical profession and in big industry (where it first began). An ever growing list of professionals are leaving the country for Canada, USA, Europe or elsewhere in the Arab world. Peer recognition and the nature of active 'brotherhood' in the scientific networks facilitate this reclassification; first, of the most eminent professionals. There is no point hurling abuse at those leaving (the ones devoted to their vocation) when we know how bad the conditions, to which their talents are subjected, here are. Neither is there any point dreaming that they might be called back or return on their own free will, unless a fresh project is offered.

The fact is that the exodus is of mammoth proportions. An additional complication arises here. Since it first began in 1965, the 'Arabicizing' of schools, which has spread into every level of education, has produced a younger generation educated entirely in Arabic, while the professional language of the laboratory heads is French (secondarily, English). Beyond their differing first experiences of life and the different nature of their grounding (teaching methods and conceptual approaches), communication is rendered even more difficult because, until very recently, the Arab and French tongues had been completely opposed—like the symbols of two conflicting *Weltanschauung*. This politicizing of the 'language' question (content apart) polarizes attitudes and complicates integration in work teams. With scientists migrating and the generations having trouble in communicating, some of the most sure-footed laboratories are afraid for their survival. Since this is not a time for new creations, Algerian research is today reminiscent of the rock of Sisyphus: *hauled halfway up the slope and threatening to roll back down again.*

NICHES OF SCIENCE: One of the strong points today is medical science. It stands for more than one-third of the production registered by the international bibliographical databases (Table 2.6). Exceptions apart, this is work carried out within the framework of laboratories linked to a university chair and healthcare service. Such research is thus *niched* in the medical profession and this feature seems to ensure its resistance. 'There isn't any interest recognized in research without healthcare here', says a professor of endocrinology, originally trained in the most basic research. 'That's why I requested a healthcare service at the same time as my laboratory'.[20]

**TABLE 2.6**
**Relative Publication Outputs by Main Research Areas**

(*Percentages*)

| *Research Areas* | *ONRS (1975–83)* | *PASCAL (1981–86)* | *ISI (1981–86)* |
|---|---|---|---|
| Clinical Science | – | 28 | 23 |
| Bio-medical Science | – | 9 | 12 |
| Total Medical Science | 69 | 37 | 35 |
| Other Biological Sciences | – | 17 | 7 |
| Chemistry | – | 13 | 22 |
| Math–Physics | – | 16 | 22 |
| Engineering Science | – | 7 | 11 |
| Earth–Ocean–Atmosphere | – | 10 | 3 |
| Non-medical Science | 31 | 63 | 65 |

The teachers at the top of the hierarchy are often recognized researchers.[21] Furthermore, the medical profession takes pride in its work. It takes an interest in difficult diagnoses, it has a taste for self-perfection, and pictures itself pushing back the frontiers of its powers through technical moderniz- ation and the development of knowledge. That is undoubtedly why they are seen as the figureheads of top-level multi-talented professionals, who are at the same time healers, educationalists and researchers—thus considered to be 'complete men'.

The medical researchers' activities are also respected because they occupy the highest status levels the profession recognizes in its ranks—professors who are heads of departments at the university hospital. It is from such positions that, championing the cause of research, they more rigorously demand the presentation of original work to accompany applications for promotion. The activity thus benefits from the authority exerted by the status levels to which it gives access. Research maintains a rather discrete presence in standard medical practices. Yet, it is nonetheless well established, provided it conforms to the values of the profession (pre-eminence of healthcare and hospital prestige). It even constitutes a strategy of self-enhancement (albeit secondary to the satisfaction in the practice of healthcare). Research can shelter in the profession and therein cultivate its autonomy drive (including vis-à-vis a 'state science').

Few other subjects offer such shelter, although there are few professions (in terms of a social body, independent of the state and the sphere of 'family' solidarities). Engineers have neither acquired that kind of cohesion nor forged their ideal from a vision of an innovating mission. Industry (as a result may be) is not one of research's privileged niches.[22] Yet, things may develop with the need to adapt to changing markets and to settle for internal know-how because outside expertise can no longer be bought. Also, and this is important, with the efforts of the new engineering associations, engineers are making efforts to revive the public image of industrialism. Now they are vaunting the idea that innovation is a fundamentally important feature of their profession.

Higher education could constitute another niche for research. We have already noticed that the universities shelter some of the best and most resistant laboratories. But it is there that the legitimacy of this activity is most contested. Many students consider that the essential role of the masters they have been assigned is to basically pass on established knowledge. A majority of teachers[23] are challenging the demands for original work made on those looking for promotion. They consider that other qualities, other signs of devotion, ought to be taken into account. And administrative pressure has long since been moving in the same direction, increasing the standing mainly of educational and managerial tasks. Furthermore, a number of procedures do systematically hinder research. The public administration establishment refuses to receive money from any source other than the state, and submits expenditure to a priori financial control, and this impedes contracts with the production sector.[24] In all, the university just provides a place for a 'partial scientific community'—where activity remains subordinate to the 'vanities' of social life and professional ambition. However, it may be fairer to say that it is divided—one part of the teaching body upholding the 'vocation' (a minority, except in mathematics, chemistry and some areas of physics) and the other refusing it.

Paradoxically, research projects are now most favourably welcomed in the engineering schools (attended by some of the best students).

The best 'niche' could be said to lie in the researcher profession itself. Full-time researcher status does exist, no matter how minimally widespread it may be. The work takes place in research centres, chiefly those that have chosen to ally themselves with the technical ministries. Yet we have seen what a sterilizing strategy this can be. The researchers there work free of standard professional norms, publication demands, comparison with peers, etc., but have not really replaced them with any new, autonomous ones. In a few other centres under the university, the quirks of status demand that the few full-time researchers are paid from the institution's own coffers. Because of this, all members (including university academicians receiving pay from other sources) are compelled to go out and hunt for contracts. This is exhausting, sometimes monotonous and, at the end of the day, sterilizing. It can wear out the will-power of the best of them. The cases of both university and full-time researchers show that purely statutory institutionalization will provide scientific communities with neither guarantees nor the best shelter. A distinction must, therefore, be drawn between institutionalization and professionalization. The former occurs with the sometimes tardy interest the state takes in science. The latter involves the transition to routine, following the gaining of an autonomous social role and social legitimacy, and the assimilation of its norms and ideals.

STYLES OF SCIENCE: The 1972 national debate has been just about the only one on Algeria's S&T options to touch the imagination of the public. Although the options have changed, it does not seem as if another is likely to take place for the time being. The interest of the state has gone and that of civilian society lies dormant. Yet, for all that, scientific activity has not come to a standstill, and moves are afoot to restructure the scientific field.

The middle period (that of ONRS) is the one to have stamped its mark on today's most established styles. Its code of ethics was one of a 'national development-oriented science'. It brought in a form of 'asceticism' which involved playing an active role in the world rather than rejecting it.[25] An important driving force was the feeling of what one owes to oneself and to the country. It goes hand-in-hand with a defiance of undue pressure from other spheres or other social bodies such as political powers, privilege-seeking families or neighbourhood groups. Here we can see scientific activity striving for relative autonomy. This trend is working more to enhance the value of 'travel' (which characterized early life for many of the founders) and its principles of openness, rather than questions of roots and loyalty towards traditional groups of affiliation. It is bracing itself in case it is forced out on to the fringes in order to maintain a now firmly established 'vocation'. At the same time, study subjects are chosen with foreseeable local needs in mind. This is not to say the choices are steered by governmental instructions but, on the contrary, many scientists complain about having lacked such guidance. They are the ones who have been scrutinizing their environment and transposing their knowledge so as to adapt it to what they judge to be the work of public interest.

As such, chemistry is turning to laboratory research on catalysis, which eventually ought to be of interest to the petrol companies. Mathematicians are developing their already great abilities in partial derivative equations with a view to possible applications in computer science (an industry yet to be established) or hydraulics (pipeline whirlpools and liquid flow). Sociologists are showing a preference for rural or occupational sociology. Nationalistic tones, however, are making way for a variety of discipline-specific interpretations that can even vary within each. This is due to the flexibility of the ONRS strategy, which left the subject selection to the people involved. Medical research, for example, is vaunting three styles of science: the first is propaedeutic–clinical research, of which surgery aimed at teaching is one area of preference; second is epidemiology—an action-oriented research linked to testing innovating methods of treatment and prevention in known and widely prevailing diseases such as tuberculosis and child mortality; and third is exploration—a sophisticated strategy in the choosing of rare afflictions which occur more frequently in this country than elsewhere and which are likely to affect forthcoming death rates.[26] National styles of science are thus being forged with their preferred subjects, charismatic figures and 'flagship' laboratories. The norms and ideals accommodate variants and specifications from one discipline to the other.[27]

Algerian science first emerged with the backing of the state. This gave rise to ambiguities which appeared most clearly in the third period, with the breakdowns caused by the shedding of that state support. A subtle hierarchy of disciplines had taken shape. It was not unrelated to that of social groups. Some disciplines appeared above all else like a state or government science; some of them had actually based their cognitive strategy on an ambition to become one. Research on natural risk or new energies thus paradoxically gained a higher place than chemistry or technology research which were struggling to find guarantors in industry. In the social sciences, economics set itself up as a directing science, mainly aiming to develop doctrines of development strategy and planning techniques. A certain number of sciences, whose values lay solely in the public interest, received a moderate degree of attention and support. Such was the case of medical science, in which, incidentally, action–research was held in higher regard than research with purely pedagogical aims and 'exploratory' work being the least influential. Some disciplines have been cast out or viewed with a good deal of suspicion.[28]

Economics did not survive the withdrawal. It sank without a trace when the once firm ideology of national planning upon which it had built its claim to the scientific helm turned to quicksand. Institutions in agriculture and oceanography, which rather than seeking out partners of their own chose to throw themselves into the arms of the state, paid the price by being reduced to simple, service laboratories. In a number of disciplines, the younger generation found itself having trouble deciding which research subjects to follow. Some leapt at the problems offered by the mainstream of world science. Others plunged into empirical studies on fashionable headline subjects of the day. There was a growth of 'individual' work projects. Some were ingeniously plagiaristic. Others amounted to little more than a rehash of existing knowledge and thus served only to saturate. Such teething problems were due to the fact that the research system, which recurrently confronted changes, did not have time long enough to infuse professional norms and the drive for scientific autonomy was taking a back seat to personal career strategies.[29]

The winds of cognitive renovation have not yet blown in. If fresh styles are emerging, it is paradoxically due to the new developments in world science and the ripples they produce here through on-going cooperation, post-doctoral training and expatriate researchers keeping contact with their colleagues back home. In particular, advances in techno-sciences or recourse to sophisticated methods radiate the most appeal. For sure, this is a time when all sorts of styles of science are joining forces in a pan-disciplinary attempt to safeguard a minimum of research activity. We can nevertheless detect an underlying wrestling in several fields and sometimes a wild struggle of newly opposing styles. In biology, for example, a school of thought vaunting painstaking fieldwork, multi-disciplinarity, application, experimentation in stations or rural environments, whose area of 'excellence' is the environmental sciences constituted at the botanical laboratory and the Centre d'Etudes des Zones Arides (Arid Zones Research Centre), is finding itself opposed by a movement promoting molecular biology. The latter field, with its laboratory work, top-level research at the heart of the discipline and a trend to publish in prestigious international journals rather than 'local' journals, seems to have an upper hand. In terms of practical action, it devises more initiatives in genetic engineering than biological control.[30] Other disciplines could have served to illustrate our point, but the conflict between these two is particularly fierce and typical. It brings the inventive styles of a local, 'national' science, still very much imbued with the constructive nationalist upsurge, face-to-face with the ambitions stemming more directly from the mainstream with its powers of attraction and renovating approaches—for world science did not take to the sidelines when Algerian science was 'suspended' and Sisyphus began serving his sentence.

# Annexure

## The Algerian Research System

This system includes today:

1. Centres and teams which most often have been created or re-established by ONRS during its short life. Among them are:
   - The 'historical' centres inherited at independence such as the Observatoire Astronomique (1880), the Institut de Météorologie et de Physique du Globe (1883), the Institut Pasteur d'Alger (1894), the Institut d'Océanographie (1930), the Institut de Prospection Minière (1942) and the Anti-cancer Centre (1950). Other centres have disappeared or drastically changed their orientations. This is the case for the old institutes such as the Institut de Recherches Sahariennes (1937), the Institut d'Hygiène et de Médecine Coloniale (1923), the Institut de Géographie et d'Urbanisme (1937–42), the Institut d'Archéologie et d'Ethnologie, and the Centre de Recherche en Anthropologie, Préhistoire et Archéologie (CRAPE).
   - Some fifteen new centres created by ONRS, in particular in the following research areas of agronomy, biological resources, arid zones, geo-sciences, animal and human biology, astronomy, astrophysics, renewable energy, scientific and technical information, regional development, applied economy, land planning, architecture and urbanism, history and linguistics. Research in computer science and mathematics, chemistry and physics as well as clinical medical research are most likely to be carried out within university laboratories. ONRS has created more than eighty such laboratories.
2. The 'strategic' centres such as nuclear studies established under a separate entity. (A centre on nuclear studies was created as early as 1950.)
3. Research centres under technical ministries. Today, they are mainly concerned with technical service functions (agricultural tests, quality control). A few of them are conducting development research projects (building and public constructions, hydraulics, public health, statistics, demography–sociology).
4. Laboratories established by the big state enterprises chiefly for electricity, gas, mining, construction materials, and of course hydrocarbons, and the iron and steel industries (SIDER)—each of them with its own research centre.

## The Human Resources

The evaluation of the number of active researchers is problematic. In 1991, the Ministry for Higher Education estimated that about one-fourth of the teaching staff was involved in research activities on a part-time basis (one-fourth to one-third of their time). Thus, Algerian universities are the home to some 700 full-time equivalent researchers for a total teaching staff numbering approximately 10,000.

In 1985, there were approximately 300 researchers in the 'productive' sector and slightly more than 100 in the 'strategic' sector. Altogether the Algerian research potential would thus correspond to some 1,000 full-time equivalent researchers. Yet, some 7,000 to 8,000 people are participating in R&D activities on a part-time basis if one were also to include PhD candidates, some engineers and some medical doctors.

## Notes

1. Still having, at this stage, trouble being accepted by the Academy and the profession.
2. Research sponsored by the Institute Pasteur in North Africa resulted in two Nobel Prizes in medicine: one to Laveran in 1907 for his work on malaria; and the other to Nicolle in 1928 for his work on typhus.
3. An Académie des Sciences Coloniales was created after the First World War. Two other important colony-oriented metropolitan institutions for the training of colonial scientific personnel were the École Supérieure d'Agriculture Tropicale and the Institut de Médecine Vétérinaire Exotique. By 1930, some twenty agricultural stations and a high school of agriculture were established in Algeria (Bonneuil and Kleiche, 1993).
4. In 1960, there were almost 2,000 Algerian students. Of these, 1,200 were enrolled in France and 800 in Algeria, that is, 12 per cent of the colony's total student population of 6,500. Let it be known that at that time, 90 per cent of Algeria's total population was Algerian. Further details can be found in the excellent work of Pervillé (1984).
5. French colonial law made a clear distinction between Algerians, known as 'French-Moslems' and European settlers known as 'French'. This means of identification disappeared in 1958, but then the Algerian students claimed it back to draw a political line between themselves and other associations, the Association Générale des Etudiants Algériens (AGEA—Algerian Students Association) for example. The defiant stance of the 'M' (for Muslim) was a decisive factor in the 1955 founding of the Union Générale des Etudiants Musulmans Algériens (UGEMA—General Union of Algerian Muslim Students). It disappeared altogether in 1962, with independence and the creation of the Union Nationale des Etudiants Algériens (UNEA), only to re-emerge some thirty years later when the first Islamic student associations were formed.
6. The 'inner circle' was composed of the first Algerian students to sign up with the nationalist independence movement at a relatively early stage: Mohammed Seddik Benyiahia, later to become Minister for Further Education and Scientific Research; Belaid Abdessalam, the future Minister for Industry and Energy, considered to be the 'father' of Algerian industrialization; M. Baghli, who during the 1970s, was to take charge of setting up the Boumerdes technology complex; etc. The real collective brain of what was to become the 'Algerian model for development' and its accompanying S&T policy was composed of a few dozen nationalist militants from the university.
7. Gouvernement Provisoire de la République Algérienne (GPRA—Provisional Government of the Algerian Republic).
8. In 1961, the Algerian grant-holding students sent abroad by the FLN numbered something in the region of 2,000. Arabic countries headed the hosts list: Tunisia (536), Morocco (440), Egypt (130) and Iraq (120). Among the Western countries, Switzerland (135), West Germany (175) and USA (40) were prominent. The Eastern countries comprised of GDR (82), Yugoslavia (40), Czechoslovakia and the USSR (35 each).
9. It may be pointed out that despite the disturbances of the transition period, there were French researchers stationed in Algeria, both from individual choice and as a part of the cooperation between France and Algeria.
10. For a detailed account see Labidi (1992).
11. Local journals of good tradition, and new ones created by ONRS, were provided the necessary funding to appear regularly, such as the *Revue d'études juridiques*, the *Bulletin d'histoire naturelle d'Afrique du Nord* and the *Archives de l'Institut Pasteur d'Alger*. New journals were also blossoming. Thus, the Institut Agronomique, the Centre de Recherche

en Architecture-Urbanisme, the Centre d'Etudes et Recherches en Aménagement du territoire, and the Centre de Recherche en Economie Appliquée were creating their respective cahiers, whereas the Institut National de Santé Publique published a bulletin. Most of these journals, however, have disappeared since 1985 with the exception of the *Cahiers du CREAD*, *Cahiers du CENEAP*, and the *Bulletin de l'INSP*.

12. In these countries, the production sector is instructed by the state to invest in long-term research programmes in collaboration with universities: a useful tool for carrying research results through to development and marketing.
13. For a detailed analysis on this see El Kenz (1995).
14. The Centre de Recherche en Economie Appliquée pour le Développement (CREAD), Algiers is currently conducting a survey on this matter.
15. Out of the 370 research projects, corresponding to the nationwide activity of 2,100 university researchers, submitted in 1990, 25 per cent were in the social sciences and the arts. Biology was on top with fifty-seven projects (456 researchers), followed by electronics (forty-three projects, 154 researchers), physics (forty-two projects, 214 researchers), mathematics/computer science (thirty-one projects, 125 researchers), and metallurgy and mechanical engineering (thirty-three projects, 107 researchers). The number of teachers participating in research activities was highest at the University of Bab-Ezzouar (496 of the 723 teachers being researchers, that is, 68 per cent). Then came the University of Oran (293 researchers out of 519 teachers) and the Alger Centre (233 researchers out of 698 teachers). For all other universities, this ratio falls to around 20 per cent, at times even around 10 per cent. We must point out the good standing of the grandes écoles, the Institut Agronomique, the Ecole Polytechnique and the Ecole d'Architecture d'Alger, all of which are in the region of 50 per cent.
16. See the epigraph of this chapter.
17. See Annexure.
18. Here, the alliances pass via a flowering of scientific societies which are open to discussing any kind of research report and provide a platform for leading scientists.
19. In many ways this strategy helps them to combat opposition mounted by the technical ministries who are more in favour of promoting training schemes geared to producing technicians and repairers.
20. During 1990 and 1991 we have conducted several interviews with a wide range of scientists in Algerian universities. See Waast (1993).
21. Their services are appreciated by patients and sought after by the students. Very few doctors, it is true, will indulge in or even have a thought for research in their ulterior practices.
22. It tends to react rather in defiance of dreamers who are incapable of instantly mending a machine and who suggest changes that disturb the shop-floor social structure while shrugging off the categorical requirement of immediate production.
23. The teaching body has suddenly and massively expanded with the influx of students, and many of its members have not yet had time to become exposed to research.
24. It thus makes a perfectly complicated tangle of the most routine operating procedures, such as the purchase of basic consumables, funding for field trips or attending scientific meetings. In the hands of authorities who are not always so favourably disposed towards researchers, the slow-moving wheels of authorization can thus become formidable instruments of obstruction.
25. This is expressed in the generally required qualities of painstaking work, serious mindedness (in the method), intense (scientific) production, and an ideal of selflessness, simplicity and discretion. One stimulus lies in the pride of 'doing it alone' (building one's own tools and developing personal experimental opinions in examining controversial theses). Tenacity—the steadfast refusal to give in—is taken to be of utmost value.
26. They are suited to longitudinal study and there is good reason to consider them as shortcuts in the advanced questions stirring the world of international medicine such as thalassemia, certain cases of hypothyroidy, specific cancers and the Epstein-Bach virus.

27. In health, for example, loyalty prevails to public service and a desire to associate research, teaching and healthcare.
28. For example, in the social sciences, anthropology was branded as being colonial, and political science and sociology concerned with conducting small-scale qualitative surveys instead of quantitative surveys on conventional themes were disliked. The former structures have left their imprint, for even after the state withdrew it continued to have a lasting effect on the spirit of certain fields and many researchers.
29. In medical science, to the rage of the imaginative founding fathers, an increasing number of so-called epidemiological studies do little more than relay the state of the health of the population, lacking the gift of both foresight and prescription (e.g., to suggest new methods of diagnosis and prevention). In the social sciences, far too much work continues to turn on analyses of reported speech rather than field surveys, and remains far too easily cocooned in the safety of the established 'high church', that is, occupational sociology, rural sociology, the social status of women, religious values, etc.
30. Insect or pest control techniques which are a part of the environmental sciences referred earlier.

## References

**Bonneuil, C.** and **M. Kleiche** (1993). *Du jardin d'essais colonial à la station expérimentale, 1880–1930.* Paris: CIRAD.

**Botelho, A.** (1995). 'La construction du style scientifique brésilien', in R. Waast (ed.). *La construction des communautés scientifiques.* Mimeo. Paris: ORSTOM.

**El Kenz, Ali** (1995). 'Les deux paradigmes', in R. Waast and A. El Kenz (eds.). *Industrie et Recherche en pays du sud.* Mimeo. Paris: ORSTOM.

**Labidi, Djamel** (1992). *Science et Pouvoir en Algérie.* Algiers: OPU.

**Pervillé, G.** (1984). *Les étudiants algériens de l'Université française, 1880–1962.* Paris: Editions du CNRS.

**Waast, R.** (1993). 'Médecine, recherche et protection sociale', in B. Curmi and S. Chiffoleau (eds.). *Médecins et protection sociale dans le monde arabe.* Cahiers du CERMOC No. 5. Beyrouth: CERMOC.

# 3 Scientific Communities in Egypt: Emergence and Effectiveness

A.B. Zahlan

Egypt is the largest and most populous Arab country. Its strategic location and natural wealth have endowed it with a special position throughout history. The high level of creativity of Egyptians, beginning with the Pharaonic period, is attested to by their invention of the major components of modern civilization. The powerful influence of Egyptian, Phoenician and Mesopotamian civilizations on Europe was transmitted through Greece (Bernal, 1987). After the fifth century BC, Egypt was subjected to a series of foreign invasions: Greek, Roman and, finally, Arab. The Arab period, beginning in the seventh century AD, integrated Egypt into the nascent Arab–Islamic civilization, of which it became an integral part and to which it made significant contributions. The Arab–Islamic civilization established the foundations of modern S&T in three directions: (*a*) it underlined the necessity for a solid empirical base, (*b*) it introduced the mathematization of scientific knowledge, first accomplished in the field of optics by Hasan bin al-Haytham, and (*c*) it demonstrated the harmonious relationship between science and technology. In addition to these three achievements, the Arabs brought about an enormous expansion of all the known fields of S&T—from mathematics and medical science to geology—and sponsored the free diffusion of scientific knowledge across political and cultural frontiers.

After developing vigorously for five hundred years, however, Arab civilization began to decline as a result of the confluence of a number of internal and external factors. Although considerable socio-economic development occurred subsequently in various parts of the Arab world, yet, Arab S&T continued to decline. Beginning in 1498, with the entry into the Persian Gulf of the Portuguese navy under Vasco da Gama, the Middle East became exposed to European naval power. The Portuguese wreaked havoc on the Arab international trading system, severely hitting its maritime arm. The Ottomans assumed power over many parts of the Middle East in 1517, and thereafter protected the region from the invasive policies of various European powers for three hundred years. By 1798, Ottoman power had declined to a level where it was no longer able to defend the region. The Arab region was subsequently exposed to a series of land invasions by European powers, which eventually took hold and initiated a period of European colonization.

There are considerable volumes of publications on the development and status of education and science in the Arab world during the last two hundred years. Much of this literature is of a descriptive nature and a great deal remains to be investigated before a critical understanding of the formation of the modern Arab world is achieved. Despite the decline of its scientific and technological capabilities, the Arab world was not a *tabula rasa*, ready to be fertilized by European science; furthermore, science was not transferred through colonial scientists or through the 'benevolence' of colonial policies.

This paper is mainly concerned with the present state of S&T in Egypt, with special emphasis on some aspects of the effectiveness of its scientific communities. The paper will first provide brief background information and then set the subject in a regional context.

## Science and Technology: From 1800 to 1947

Napoleon Bonaparte conquered Egypt in 1798 in a bid to secure a direct route to India. He was accompanied by a scientific mission. Europeans maintained a slender research base in Egypt for a long time. The output of the scientific team that accompanied Napoleon provided Egypt and European governments with valuable and seminal information throughout the nineteenth century. The utilization of this information was often disastrous for Egypt. A notable example is the construction of the Suez Canal. The British, for whom India was the cornerstone of their empire, could not tolerate their rivals, the French, straddling the shortest route to India. British policy throughout the nineteenth century was dedicated to the preservation of the Ottoman Empire in its weak condition in order to prevent any European power from gaining influence there. Admiral Nelson was therefore despatched to remove France from Egypt, which he did.

Shortly afterwards, Muhammad Ali, a senior Albanian officer in the Ottoman army, saw a golden opportunity for establishing his personal control over Egypt. Through a succession of moves, he placed himself in control of Egypt and became the Viceroy of the Porte. Muhammad Ali quickly grasped the importance of technology. He set himself the task of establishing a powerful army, schools to train military manpower, military industries, a medical school to train doctors for the army, and the development of the agricultural sector to generate the revenue to sustain his power. He also attempted to develop the textile industry by monopolizing the means of production and subjecting traditional producers of textiles to heavy fines. In order to achieve his objectives, Muhammad Ali sponsored a substantial number of Egyptians to study abroad (mostly in France) and imported much larger numbers of European army officers and instructors to staff schools and the army, and to plan and manage physical investments in Egypt. He contracted with a number of European firms to establish industrial firms to process agricultural output: cotton, sugar, indigo and other products. He also employed a large number of foreign doctors, technicians and engineers to establish a medical school, and to plan and execute large-scale engineering works to expand irrigation and water storage capacities.

Muhammad Ali invented the modern turnkey approach to total technological dependence; he believed that this method best fitted his ambitions to secure undisputed control over Egypt (Zahlan and Said Zahlan, 1978). Egyptian manpower, trained in Egypt and in Europe, acquired prescribed technological capabilities successfully; however, the political regime in force was loath to depend on national manpower. In the military fields, the reliance was on Europeans (mainly French), Americans (mainly Confederate army officers after the end of the American Civil War), Albanians, Circassians and others. Egyptians served as low-ranking administrators and officers; they were kept far removed from high-ranking civilian or military positions. The technologically dependent turnkey approach failed to sustain the political and economic development of Egypt: it led Egypt from one economic and political disaster to another. The collapse of the Egyptian economy in the late 1870s led to its occupation by Britain in 1882—an occupation which lasted, effectively, until after the Second World War.

## Relevant Educational Development in the Region up to 1947

The establishment of national educational institutions in the Middle East was on a modest scale throughout the nineteenth century. Arab nationals went in increasing (although small) numbers to study in Europe and later in the United States. But the graduates of the new national institutions, as well as those from institutions abroad, were not prepared culturally or professionally for the scientific and technical jobs at hand. During the colonial period, the development of public education had been severely restricted: the largest expansion was through private schools and was on a limited scale due to the low economic activity in the region.

In addition to limited governmental educational programmes, Anglo-Saxon (British and American) Protestant missionaries sought to spread their faith in the region. These missionaries were motivated by a Messianic millenarian movement called the Second Great Awakening which imposed great urgency on those who believed in it. According to this movement, Christ's reign on Earth would begin once the Jews were 'restored to Jerusalem' and converted to Protestantism. Protestant missionaries in the Middle East set out to fulfil their Messianic objectives; they sought to convert the Arab-Jewish communities, where they met with strong resistance. Consequently, the missionaries began to divert their attention to non-Protestant Christian communities in the region. The presence of these missionaries very quickly induced a substantial increase in the activities of French (Roman Catholic) religious and educational institutions. A by-product of this missionary activity was the founding of the Syrian Protestant College (SPC), now the American University of Beirut, in Beirut in 1866. Within a few years, the French Jesuits had founded the College St. Joseph in 1871, also in Beirut.

Maybe the first graduate from SPC to make a mark on scientific thought in the region was Shibli Shummayyil, who after obtaining his degree in medicine from SPC in 1871 spent a year studying in Paris. While in Europe, Shummayyil learnt about Darwin's new theories. Upon his return to the Middle East, he settled in Tanta (Egypt) where he established a medical practice. He devoted much of his spare time to spreading the theory of evolution. Shummayyil started a debate of considerable scale among religious circles and intellectuals in the region. Interestingly, he had a remarkable influence on the American missionaries at the SPC. The views diffused by Shummayyil won over one of these professors, and this conversion to the theory of evolution led to the dismissal of that professor in 1882. As a reaction to the dismissal of a popular instructor, the students went on strike—this was the first student strike in the region in modern times. This was a major upheaval at SPC and for its medical student body.

The diffusion of the science of evolution among American professors at SPC was by an Arab graduate who had learnt the science at source. The SPC was adamant in its fundamentalist approach to science; all the medical students were expelled and most of the foreign faculty of the medical school resigned. The heated debates initiated by Shummayyil did not lead to any proper scientific work relating to the theory of evolution (Ziadat, 1986). The significance of this analysis is that it was Shummayyil who was the conduit of modern science and not the missionaries who stood in opposition. The discussions and public debates on the theory of evolution did not lead to scientific research in this, or any other fields of science. It was not until after the Second World War, when the number of university graduates had reached a sufficiently large size and maturity, that scientific research and the deliberate pursuit of S&T began to take shape.

All research work undertaken in the region was part of some European programme. A small number of national engineers began to develop new industries and to participate in consulting and contracting. Some of the work of geological explorations and agricultural development was funded by the Egyptian government and employed competent Egyptian geologists. Until independence, the involvement of nationals in scientific and technical activities was very limited. Medicine, pharmaceutical sciences and agriculture were the leading fields where nationals were actively participating.

The level of activity did not result in the generation of new scientific knowledge; yet, there was wide interest in scientific advances undertaken in Europe. The absence of national institutions and policies to promote scientific work was a major obstacle.

## Transition to Independence

The British occupation of Egypt in 1882 reduced the distinction between various ethnic groups and thus had a positive impact on the evolution of social cohesiveness. The economic policies of Muhammad Ali had promoted the emergence of a new class of Egyptian rural and urban notables who accumulated capital from their activities in agricultural production; this new class was to play an important role in the early industrialization of Egypt under the leadership of Muhammad Tal'at Harb and the Bank Misr which he established (Davis, 1983). But the industrialization of Egypt under the Bank Misr did not espouse a radical departure from the prevailing attitudes towards technological dependence. The Bank Misr experiment had many positive aspects, but failed to lead either to a major transformation of the Egyptian economy or to a constructive attitude towards S&T. Thus, both public and private sectors pursued technology policies which were grievously flawed and which did not contribute to the promotion of national scientific and technological communities and institutions.

Surprisingly, Arab political and social analysts have not attributed the disasters inflicted on Egypt to the social, economic and technological policies adopted by Muhammad Ali and his successors. On the eve of political independence, planning and project implementation were being carried out by European firms. The political elites who assumed power after independence (circa 1950s) had had no education or experience in S&T. Upon assuming political independence, the different Arab governments, and especially Egypt's, paid only nominal attention to the importance of education and S&T. Education and the establishment of national institutions were given high priority, but the new educational programmes were planned bureaucratically and lacked a creative content. The world of learning and that of development policies and practices (that is, the world of work in a developing society) were moving separately. There was no understanding of the importance of coordination and integration of these two different activities. Thus, the planners of newly independent Egypt had not acquired an understanding of the vital role that science policy plays in bringing about the articulation of disparate socio-economic, educational, and R&D activities.

## Independent Egypt

A general belief in the importance of technology and of professionals had taken root in Egypt before independence and before the Second World War. The War years delayed the adoption of suitable actions. Egyptian elites were already considering the establishment of some national organizations in the hope of giving an impetus to institution-building (Sabet, 1969). The Fouad I National Research Council was established just before the Second World War. In 1950, it compiled information on Egyptian scientific manpower and did not find it wanting; there were already considerable numbers of scientists holding PhD degrees from European and American universities. Egypt was ahead of China in the availability of scientific manpower (Zahlan, 1980). The challenge was how to put this scientific manpower to good use.

A military coup in 1952 toppled the regime of Muhammad Ali's dynasty and replaced it with a republican government. The new Egyptian government sought to accelerate social and economic development. New policies were adopted and new institutions were established to implement these new and ambitious policies. The new 'revolutionary' government of Egypt adopted policies that promoted the expansion of education at all levels, industrialization, the establishment of research institutions and a ministry of science. Interestingly, the measures taken by the new government were no less arbitrary than the measures taken by previous Egyptian governments; although scientists were formally consulted, these were no more than gestures, for their recommendations were either vetoed or ignored (Zahlan, 1980).

The new policies did move away, to some extent, from the comprehensive turnkey approach that had prevailed in Egypt. But they did not give adequate attention to institution-building or to the acquisition and accumulation of technology. Government circles only had a limited understanding of the motive force behind scientific work, the relevance of science policies, the importance of innovation and R&D, and the characteristics of a fruitful R&D environment. This did not mean that the Egyptian government did not seek and receive the advice of international organizations in this domain (there were, for example, numerous UNESCO missions to Egypt). The political culture prevailing in Egypt did not permit the adoption of essential reforms in the domains of planning, technology policies and manpower development. The new government of Egypt, just like the old one, was obsessed with the importance of personal loyalty to the regime rather than with the competence of professionals and the institutionalization of policy and procedures; government officers had a blind belief in the power of subservient bureaucracies and in the capabilities of such institutions to 'make things happen'.

Scientists and engineers in Egypt were rapidly increasing in number thanks to government subsidies for study abroad; but these young scientists and engineers found themselves increasingly alienated from public service and sought the brain drain route out of their predicament. The beginning of a massive brain drain began to take shape. Egypt lost large numbers of its professionals to other Arab states, to the US and to Europe. Despite these negative features, Egypt was able to place itself among the leading Third World countries as measured by per capita output of scientific publications. The development of Egypt during the past fifty or more years has not been constrained by a shortage of professional manpower or by capabilities in scientific research.

## Education in Egypt

The development of S&T depends on a literate and well-educated society. The expansion of the Egyptian educational system has been pursued at all levels: primary, preparatory, secondary and tertiary (university). By 1990, school enrollment at the primary level stood at 82 per cent of the age group, while participation was at 54 per cent in 1980. Enrollment in the preparatory and secondary levels of education is being expanded: 3.5 million at the preparatory level in 1990, up from 2 million in 1985; 1.5 million at the secondary level in 1990, up from 1.4 million in 1985. Technical education is still on a limited scale: some 103,000 students were enrolled in 1990, with an overwhelming majority in relatively poor-quality commerce programmes.

The quality of education as measured in terms of students per teacher (thirty-five to forty-five), facilities, curricula and academic standards leaves much to be desired. Furthermore, there does not appear to be a forward trend towards improvement in the quality of education.

### University Education

There were thirteen universities in Egypt in 1991. These offered educational programmes in all the traditional fields of learning. The second oldest university in the Arab world is the Al-Azhar in Cairo, which was founded in AD 972; the oldest is el-Karawan in Tunisia founded in AD 859. The modern system of education was developed without any relationship to Al-Azhar. The first college in the region was the medical school of Kasr al-Aini (Cairo), established in 1827. The second, the School of Engineering (Cairo), was established in 1831. A law school was established in Cairo in 1868. Cairo University was founded in 1925; it was followed by Alexandria University (1942), Ain Shams (Cairo) (1950), Assiut (1955), the modernization of Al-Azhar University (1961), Tanta University (1972) and al-Mansourah University (1972). Seven of the thirteen universities have been established since 1970.

The contents and scope of higher education, however, fall below the standard programmes on offer in industrial countries. Thus, many of the new areas of knowledge which have been developed during the past ten to thirty years may be taught either superficially or not at all. The expansion of higher education in Egypt since the 1950s was not, however, accompanied by adequate attention to the quality of education, to the relationship of enrollment to facilities, or to the development of academic disciplines in new and emerging academic areas in the social and basic sciences, engineering and technology. The quality of academic standards suffered considerably because of the limited research opportunities available to university professors, and the poor and congested teaching facilities. Furthermore, the system of governance of universities has remained highly underdeveloped, and does not provide the proper environment for intellectual and creative activity.

Egypt has accumulated a substantial population of university graduates over the past forty years. No official figures are published on the total professional manpower available. Statistics focus on the annual number of graduates. The outflow of Egyptian professionals to the Arab countries and the brain drain to other OECD countries make it difficult to estimate the numbers remaining at home. It is unlikely that the total pool of university graduates available to Egypt exceeds 1 million, inclusive of graduates in law, the arts and humanities. There were, in 1990, more than 120,000 engineers and 50,000 MSc and PhD scientists who were involved directly or indirectly with education, planning, and/or scientific and technical research. There are 50,000 scientists employed in the educational sector (75 per cent), service sector (13 per cent) and production sector (11 per cent). About half the scientists (21,000 out of 45,000) hold a PhD degree (Hubaysh, 1992). Fifteen per cent of the age group 20–24 are enrolled in some four-year university course in Egypt. The system of education is extensive, and as will be shown later, it continues to churn out substantial numbers of graduates in a large number of fields.

Since the mid-1980s, the government has sought to reduce the number of university students in order to make the system of higher education more manageable. The proclaimed purpose of these changes in enrollment is to spread the available budget to a smaller number of students. Table 3.1 shows that an overall decline of 14 per cent in enrollment was achieved over the period 1984–1990. This decline was registered in most disciplines: arts, science, engineering and law. The decline, however, varied according to university, gender and discipline. Egyptian universities are so severely under-funded that even a reduction of 15 per cent, or even 50 per cent, in enrollment may not result in noticeable changes in quality.

Egyptian universities graduated 115,000 students in 1984–1985 and 105,000 in 1989–1990. Of these, 31,000 and 26,000 respectively obtained their degrees in basic and applied sciences. The number of graduates is still

TABLE 3.1
Number of Students Enrolled in Egyptian Universities by Major Discipline

| *Discipline* | *1984–85* | *1989–90* |
|---|---|---|
| Grand Total | 682348 | 569126 |
| *Humanities* | 505267 | 431220 |
| Arts | 69593 | 62704 |
| Commerce | 154182 | 114501 |
| Law | 74935 | 72020 |
| Economics | 1171 | 1409 |
| *Science and Technology* | 167541 | 137906 |
| Medicine | 28443 | 26885 |
| Pharmacy | 7857 | 6639 |
| Engineering | 35350 | 29092 |
| Agriculture | 33863 | 23185 |
| Sciences | 23302 | 18621 |
| Technology | 12708 | 6919 |
| Electronics | 1875 | 1972 |
| Petroleum and Mining | 476 | 507 |

Source: *Statistical Yearbook*, 1991. Cairo: Central Agency for Public Mobilization and Statistics.

large. These young people are entering a labour market that is already saturated—investments in Egypt have not been able to employ available professional and non-professional manpower. Hence, there is a high level of unemployment and the constant outflow of manpower out of the country. The challenge, which has still to be addressed, is to increase the absorptive capacity of the economy for investment and manpower; such reforms, however, involve major changes in science policy.

Tables 3.1 and 3.2 show the distribution of students and graduates by discipline. The number of university graduates has been increasing at the rate of more than 100,000 a year; this is in addition to the number of Egyptians who study abroad. Many of these graduates migrate to Arab countries or other countries. Thus, the annual rate of increase of the pool of university graduates is increasing at a relatively high rate—probably somewhere between 10 and 20 per cent, depending on the proportion of graduates who remain in Egypt. Unemployment among university graduates is also fairly high; no systematic statistics have been published. However, figures have been quoted that claim that more than 30 per cent of the engineers are unemployed.

## Regional Influence of Egyptian Universities

The population of Egypt is the largest of all the Arab countries (25 per cent of the population of the Arab world). Muhammad Ali initiated the first

TABLE 3.2
Number of Graduates from Egyptian Universities by Major Discipline

| *Discipline* | *1984–85* | *1989–90* |
|---|---|---|
| Grand Total | 115727 | 105144 |
| *Humanities* | 84841 | 79009 |
| Arts | 12667 | 12004 |
| Commerce | 28611 | 22673 |
| Law | 11536 | 12799 |
| Economics | 191 | 157 |
| *Science and Technology* | 30876 | 26135 |
| Medicine | 5105 | 4101 |
| Pharmacy | 1450 | 1179 |
| Engineering | 6502 | 5417 |
| Agriculture | 6789 | 5323 |
| Sciences | 4516 | 3906 |
| Technology | 1687 | 1376 |
| Electronics | 254 | 356 |
| Petroleum and Mining | 81 | 69 |

Source: *Statistical Yearbook*, 1991. Cairo: Central Agency for Public Mobilization and Statistics.

effort in the region to introduce European technology and know-how. It may not have been undertaken in the best possible way, but it still had a massive impact, not only on Egypt but on the entire region. Egyptian institutions and universities were usually the first in the region; they attracted students and set role models. Egyptians served as advisers and consultants; they supplied presidents, deans and professors for many of the universities established in the other Arab countries. For better or worse, many of the new universities, especially those in the Gulf states and Saudi Arabia, were deeply influenced by the experience of Egyptian universities. Unfortunately, the transfer of the model often took place without a critical evaluation of what is best to transfer and what should have been adapted before adoption. During the nineteenth century, Egypt suffered from a shortage of labour and attracted all types of professionals and workers from the Arab countries and Europe. Since the 1950s, Egypt has supplied many of the countries of the region with teachers, university professors and technical services. Egypt commands a special place in the Arab world. It is the home of many Arab regional institutions, such as the League of Arab States; many other regional institutions are also based there.

## Research and Development Activities

Research work is pursued in thirteen universities and in 200 research institutes. There were, in 1990, more than 66,000 researchers in Egypt; of these, 21,000 held a PhD, 12,500 held an MSc, 16,000 a BSc and 17,000 a Technical Diploma. These researchers were distributed as follows amongst the various disciplines: 11.5 per cent in engineering, 16.7 per cent in medicine, 21.9 per cent in agriculture, 23.8 per cent in the basic sciences and 26.1 per cent in the social sciences.

The Academy of Scientific Research and Technology (ASRT) has published a considerable volume of information on scientific activity in Egypt (ASRT, 1990a). In 1990, it published eight volumes (in Arabic) on the history of science in Egypt. In these volumes, the history of each department and research institution is described and the activities of its staff members are reported. The account is narrative and descriptive. Although it lacks analytical details, it provides a useful compilation of historical information (ASRT, 1990b). Figure 3.1 shows the evolution of research output of Egypt measured in the number of mainstream publications over the period 1967–1991—a seven-fold increase in output can be noted over a period of 24 years.

The universities are the major sources of scientific publications in Egypt. Table 3.3 shows the leading publishing centres. The prominence of universities can be noted, with Cairo University in the lead. Except for 1990, Cairo University has been the leading publishing institution in the Arab world. In 1990, the University of Kuwait assumed that position. Although the National Research Centre (NRC) is the largest research institution in the region—in terms of number of professionals on its staff—it does not appear in Table 3.3. In 1977, the universities of Alexandria and Cairo had similar outputs; but over the past fifteen years, Cairo University appears to have taken the lead. Some of the new universities, such as those of Menia, Manoufia and Tanta, have not been able to sustain an output of even fifty publications a year.

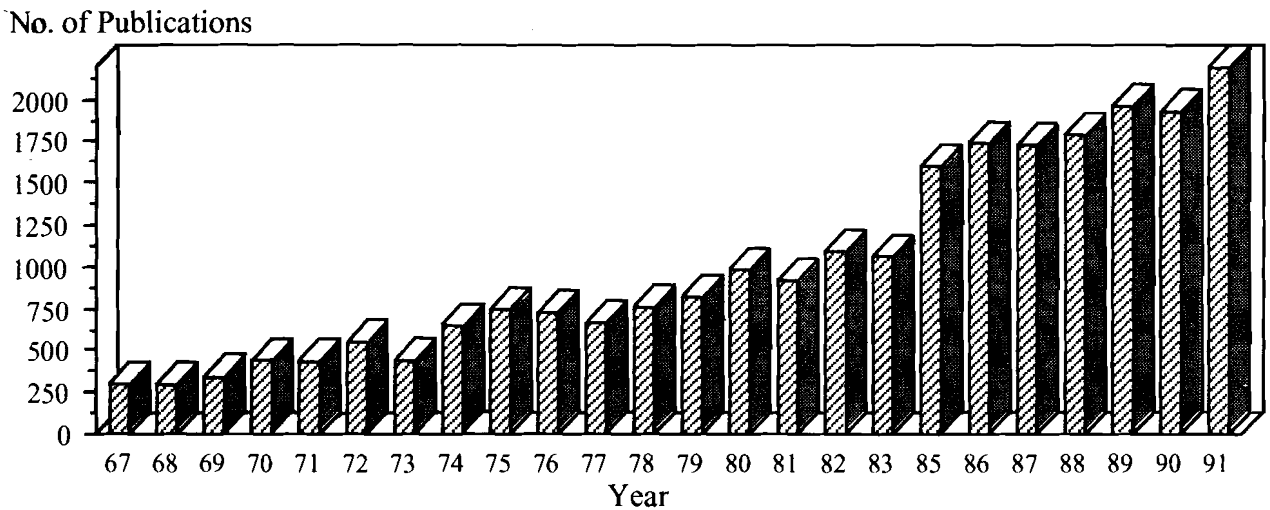
It is clear from Table 3.3 that the output of each institution is relatively small when compared with the large number of staff (66,000) participating in R&D, the number of students enrolled, or the number of persons holding a PhD degree in science. The output is less than one publication per year per ten doctoral R&D scientists. Bearing in mind that the majority (more than 90 per cent) of the publications are of a very applied nature, it appears that the performance of the system is not impressive.

## Research and Development Activities Outside the Universities

R&D is also undertaken in the institutions under the aegis of the Ministry of State for Scientific Research. The Ministry of State for Scientific Research is responsible for four major structures:

1. The Academy of Scientific Research and Technology (ASRT).

**FIGURE 3.1**
**Research Output of Egypt, 1967-1991**




Source: Institute of Scientific Information, Philadelphia, USA

TABLE 3.3
Egyptian Institutions Publishing Fifty or More Refereed Publications

| *Institutions* | *1977* | *1983* | *1986* | *1989* | *1990* |
|---|---|---|---|---|---|
| Atomic Energy Authority | – | – | (40) | 56 | (42) |
| University of Alexandria | 105 | 163 | 232 | 213 | 237 |
| Cairo University | 107 | 203 | 338 | 304 | 359 |
| University of Assiut | (40) | 86 | 100 | 162 | 160 |
| Ain Shams University | 81 | 101 | 157 | 203 | 190 |
| Al-Azhar University | – | – | 71 | 93 | 77 |
| Manoufia University | – | – | (13) | 53 | (42) |
| Mansouria University | – | – | 125 | 176 | 164 |
| Menia University | – | – | – | 57 | (37) |
| Tanta University | – | – | 69 | 59 | (44) |
| Zagazig University | – | – | 80 | 54 | 84 |

**Source**: Institute of Scientific Information, Philadelphia, USA.
**Note**: Figures in brackets indiate < 50 publications.

2. Nine research centres and institutes.
3. The Technical and Technological Studies and Research Fund.
4. The National Authority for Remote Sensing and Space Studies.

## The Academy of Scientific Research and Technology (ASRT)

ASRT was established in 1971. It is the central body responsible for the support of scientific research and for the application of current technologies in the national programmes of socio-economic development. It is also responsible for setting policies to bridge the gap between the scientific community and the demand side (industry, agriculture and other sectors) of the economy in Egypt. ASRT has given attention to the provision of scientific information to researchers. A number of services have been established to achieve this goal. The two main services are the National Information and Documentation Centre (NIDOC) and the Egyptian National Scientific and Technological Information Network (ESTINET). ASRT has also established a database on international patents and publishes a number of scientific journals.

The Specialized Councils of ASRT sponsor R&D projects. During the period 1987–1992 (Phase II), ASRT continued the support of 131 ongoing R&D projects at a cost of LE 10 million and initiated 630 new projects at a cost of LE 57.6 million. These sums of money are relatively small. Practically all of the nearly 350 projects supported by ASRT are in very applied and technical fields: food, agriculture, irrigation, construction, and so on. Thirteen were in the 'basic sciences' and twenty were in economics and management.

One of the most common difficulties in the application of technology in developing countries is the neglect of the economic and management aspects of technology. Unlike science, technology implies the production of a useful service or product; this in turn implies marketing, attention to cost, and the competitiveness of the product and service. It is clear from the allocations of funds to projects that these essential aspects of technology are generally neglected. This may be one of the factors that has worked against the utilization of local suppliers of technology.

## The Nine Research Centres

Egypt has over the years established a large array of research centres. Many of these were initiated as departments in NRC. There are now eight other research centres in Egypt: the National Institute of Oceanography and Fisheries, the National Institute of Standards, the Institute of Astronomy and Geophysics, the Central Metallurgical Research and Development Institute, the Petroleum Research Institute, the Theodore Bilharz Institute and the Electronic Research Institute.

NRC, founded in 1956, is the largest in Egypt.[1] It has 900 qualified research scientists on its staff in addition to 200 research assistants. NRC addresses many of the basic technical problems facing Egypt today. Its activities are on a basic and applied level. After it was established in 1956, there was a tendency to use the facilities as an extension of the different universities in Cairo to generate MSc and PhD dissertations. However, since the early 1970s, this tendency has been curtailed and a mission-directed management has taken over.

## The Technical and Technological Studies and Research Fund

The Technical and Technological Studies and Research Fund (Al Sanduq al-Istisharat wal-Dirasat wal-Buhuth al-Faniyya wal-Technologiyya), also known as The Sanduq, was established in 1988 by the Ministry of Scientific Research. It aims to mobilize the professional resources currently available in private and public organizations. It has a database on the available professional resources and has developed procedures to mobilize these resources, when and if required, for consultancy projects. The Sanduq executed more than 67 studies up to November 1991. These were economic–technical studies in a variety of subjects including: (*a*) assessment of existing firms and studies of specific opportunities for import substitution, (*b*) ecology and environmental studies including waste disposal and sewage disposal projects, dispersal of oil spills, etc., and (*c*) market and feasibility studies, and educational training consultancies.

### The National Authority for Remote Sensing and Space Studies

The Authority was established in 1971 in collaboration between ASRT and the US National Science Foundation. The Authority operates a well-equipped centre capable of utilizing and interpreting satellite data for the conduct of geological surveys as well as the use of aerial photography. The services of the Authority have been used extensively in Egypt in the planning of development projects, archaeological explorations, mapping, environmental studies and in mineral resources exploration. The facilities available at the Authority have been the object of constant expansion and improvement. Since 1976, the Authority has been acknowledged as a regional resource serving the Arab and African countries.

### Other Research and Development Organizations

The Ministries of Agriculture and Health in Egypt also operate a large number of research stations in agriculture and medical research (generally conducted in hospitals). In fact, some two-thirds of all publications in Egypt, as in other Arab countries, are in medicine and the agricultural sciences. Thus, medical personnel and agricultural scientists are the leading arms of R&D activity. Needless to say, practically all these publications are of a very applied nature.

## Utilization of Research and Development

ASRT has published an analysis of its R&D contributions to the socio-economic development of Egypt (ASRT, 1990a and b). It is clear from this account that the economic impact is far greater than the expenditure on R&D. Yet, the under-utilization of R&D capabilities has been clear to planners and decision makers for many years—in fact since 1940. Various reforms of the R&D system have been planned and discussed, and some measures have been adopted with a view to enhancing the utilization of existing professional resources. The potentialities are so considerable that enormous effort is required to harness them. So far, the efforts made have not been commensurate with the potentialities.

The central obstruction to the use of Egyptian potential in S&T in development arises from the absence of sound technology and economic policies. The absence of careful analyses of the requirement of the economy in terms of technical services, the over-centralization of decision making and the weakness of professional organizations have all undermined the genuine attempts made to overcome this problem. Egypt has no excuse for remaining in the Third World category.

A few illustrations of successful efforts are presented here. One of the earliest projects entitled 'More and Better Food' was initiated by ASRT in 1978. It was concerned with improving the production of a large variety of crops and animals. An important component of the project was to promote the integration of R&D institutions with the users of R&D. Substantial improvements in quality and yields were achieved (El-Nockrashy et al., 1987). A promising approach adopted by ASRT for harnessing some of the scientific talent was to sponsor, in 1990, the Science and Technology Cooperation Programme (STCP) in cooperation with USAID. The objective of the STCP was to develop bridges between the users and producers of R&D. All projects to be sponsored by the STCP have to be led by a user, that is, by the demand side. The secretariat of the STCP assists the user by developing an effective link-up between the user and the provider of the R&D. The STCP also supports the project between the two parties by funding the foreign exchange component of the research contract.

During the first three years of the STCP, sixty-four contracts were arranged between fifty-four firms (thirty-two public and twenty-two private) and thirty-six R&D institutes. The implementation of these projects involved 1,705 researchers and technicians. Of these, 35 per cent came from the user side and the balance from the R&D side. The user had to make a cash contribution. The size of these research contracts varied from $60,000 to $1 million. Although the programme is still new, the success rate has been high—more than half the projects sponsored have led to a positive economic result to the user. ASRT also established a Small Scale Industry Programme in 1988 to encourage young entrepreneurs with limited capital to establish small scale industries. ASRT initiated this programme by inviting proposals from entrepreneurs. A total of 1,500 such proposals were received; each was studied and evaluated by professionals. Forty-eight projects emerged from these 1,500 proposals; techno-economic studies proved the viability and usefulness of each of these forty-eight projects.

Four demonstration centres were established to diffuse the know-how to interested entrepreneurs, and detailed instructions and training programmes were prepared. An entrepreneur, given a small capital, can receive free technical assistance to set up a small industrial or agricultural activity. The reactions to these programmes have been very promising (El-Nockrashy, 1993).

## A Survey of Publications from the Arab Countries in National and International Journals

Comprehensive surveys of scientific output are difficult and expensive to undertake. The Committee for the Development of an Arab Strategy in

Science, established by the Arab League Educational Cultural Scientific Organization (ALECSO), commissioned a field study to determine the research output of the Arab countries.[2] The following Arab countries provided information: Algeria, Egypt, Iraq, Jordan, Kuwait, Saudi Arabia, Sudan, Syria and Tunisia. The study was based on available official and/or semi-official records of a country's publications. These records included publications in national and foreign periodicals as well as notices of presentation of papers in scientific meetings, books and dissertations presented in foreign universities. It is not certain whether these national bibliographic sources quoted only refereed journals and publications in professional journals. No information could be gathered about the editorial policies of these compilations. The compilations included research of an academic and applied nature. No information was provided on the completeness of the data utilized; many of the compilations were found to be incomplete and the bibliographic information in them was not standardized.

The data was compiled for three periods: (*a*) 1970 to 1975, (*b*) 1976 to 1980, and (*c*) 1981 to 1985. The information for the first two periods was incomplete as only four countries supplied data: Saudi Arabia, Kuwait, Jordan and Tunisia. The data showed a rapid expansion in the outputs of these four countries during each of the periods (Table 3.4). The growth has been steady and vigorous. All these findings are consistent with the twenty-five years' trend based on ISI data shown in Figure 3.1 for Egypt. The report provided an analysis of the data by field of research.

**TABLE 3.4**
**Publication Outputs of Four Arab Countries, 1970–85**

| *Countries* | *1970–75* | *1976–80* | *1980–85* |
|---|---|---|---|
| Saudi Arabia | 285 | 935 | 2553 |
| Kuwait | 264 | 533 | 790 |
| Jordan | 113 | 339 | 835 |
| Tunisia | 460 | 1103 | 1276 |

Table 3.5 shows the average number of publications by country and field for this period. According to the data, the average annual output was 1,400 publications; according to ISI records (not shown in this paper) the Arab countries published an average of 2,500 papers per year in ISI monitored periodicals. ISI shows that Arab research output in the basic sciences in 1978–1980 exceeded 4,700 or 1,600 annually in refereed international periodicals, which is in excess of the findings of the ALECSO sponsored study based on national compilations of publications at home and abroad. This means that the compilations on which the study was based were incomplete (Ahmar et al., 1987).

TABLE 3.5
**Publication Output in the Arab World by Country and by Field, 1981–85**

| *Country* | *Basic Sciences* | *Medicine* | *Engineering* | *Agriculture* | *Economics and Management* | *Total* | *Per cent of Arab World* |
|---|---|---|---|---|---|---|---|
| Egypt | 829 | 1924 | 747 | 1089 | 497 | 5086 | 70.6 |
| Saudi Arabia | 71 | 255 | 104 | 49 | 30 | 509 | 7.1 |
| Algeria | 12 | 172 | 71 | 14 | 44 | 313 | 4.3 |
| Tunisia | 12 | 146 | 40 | 57 | – | 255 | 3.5 |
| Jordan | 93 | 48 | 28 | 21 | 19 | 209 | 2.9 |
| Kuwait | 80 | 82 | 32 | 4 | – | 198 | 2.8 |
| Morocco | 57 | 80 | 14 | 42 | – | 193 | 2.7 |
| Iraq | 80 | 20 | 23 | 36 | 12 | 171 | 2.4 |
| Sudan | 19 | 31 | 11 | 83 | 1 | 145 | 2.0 |
| Syria | 28 | 34 | 29 | 21 | 8 | 120 | 1.7 |
| Total | 1281 | 2792 | 1099 | 1416 | 611 | 7199 | 100 |
| Per cent of Total | 17.8 | 38.8 | 15.3 | 19.7 | 8.5 | 100 | |

**Source**: Ahmar et al., 1987.

## Distribution of Output by Field

Table 3.5 shows that 75 per cent of the output of research work is in medicine, agriculture and engineering. This emphasizes the applied nature of research in the Arab countries. In fact, many of the publications listed under the basic sciences are in the applied sciences. Strictly speaking, R&D in advanced fields of S&T is on a very limited scale in all Arab countries. The scale of the activity is often circumscribed by a new faculty member who may have recently returned from studying or working abroad. The country distribution of the publications in international journals is very different from that in national publications. Egyptian scientific workers publish heavily in national scientific journals; this is not the case in most of the other Arab states.

## Comparison with Other Third World Countries

The research output of the Arab countries, and especially that of Egypt, compares favourably with that of other Third World countries. Table 3.6 summarizes such data. Egypt stands well above other major Third World countries. The performance of the combined Arab world compares

TABLE 3.6
Annual Per Capita Output of Scientific Publications (Average for 1978–80)

| *Country* | *Annual Per Capita Output* |
|---|---|
| USA | 890.0 |
| India | 26.1 |
| Turkey | 8.1 |
| Iraq | 19.9 |
| Algeria | 4.0 |
| Morocco | 3.8 |
| Brazil | 17.1 |
| Egypt | 34.0 |
| China | 1.2 |
| Nigeria | 14.0 |
| Mexico | 12.2 |
| Taiwan | 31.2 |
| Saudi Arabia | 26.0 |
| Republic of Korea | 4.7 |
| Sudan | 6.9 |
| Lebanon | 36.9 |
| Kuwait | 77.9 |
| Tunisia | 14.6 |
| Libya | 20.9 |
| Jordan | 17.9 |
| UAE | 11.3 |
| Somalia | 1.5 |
| Syria | 0.8 |
| ARAB WORLD | 17.3 |

**Source**: ISI, Philadelphia, USA.

favourably with the rest of the Third World in terms of per capita research output in international journals monitored by ISI.

## Arab Scientific Journals

Arab scientific journals are, at best, of limited importance. These publications have yet to attain a high level of maturity in terms of their continuity, quality, regularity of publication and uniformity of content. The bibliographic information on Arab publications serving the scientific community is incomplete. The best that could be done was to estimate their number and assess their contents by examining available records, such as those at the Library of Congress and an extant survey published by ALECSO.

The Arabic section of the US Library of Congress compiles and collects periodicals in a systematic manner. These records indicate that there were eighty-three periodicals known to the US Library of Congress that were published in Arabic in the Arab countries. The US Library of Congress was unable to obtain copies of all the issues of these publications on a regular basis. Many of these periodicals are published erratically. Thus, it was not possible for me to examine copies of all these publications to verify whether they would meet the minimum requirements of professional journals. These eighty-three periodicals were published in Egypt (forty-four), Iraq (thirteen), Saudi Arabia and Morocco (five each), Jordan and Palestine (three each), Sudan, Lebanon, Tunis and Kuwait (two each), and Algeria and Syria (one each). The largest number of these publications was in the medical field (twenty-two), followed by seventeen (mostly published in Egypt) in the basic sciences, fifteen in engineering, thirteen in agriculture, six in geology, five in general technological areas and the balance in other fields.

The only other source that could be utilized to verify these findings was the ALECSO publication (ALECSO, 1981). This listed only fifty-eight professional journals. Of these, seven were from Egypt, eight from Iraq, ten each from Libya and Morocco and seven from Jordan. The distribution of these journals by field was: medical (five), agriculture (nineteen), general science (seven), petroleum (three), engineering (five), information (seven) and the balance in other fields. Clearly the two lists do not correspond to each other. Since these journals are not published regularly, they cannot become instruments for the diffusion of useful knowledge. They lose the interest of their potential readers and the information published in them is often so late that it is obsolete.

The ISI publishes annually a series of bibliographic compilations essentially based on citations of scientific articles by the scientific community itself. In other words, the policy of ISI is that if scientists cite particular articles in particular journals, it means that they find them useful. It uses the list of cited journals as a base to compile its bibliographic lists. In 1989, the ISI included only one Arab journal in its list of surveyed journals—a journal published by the University of Kuwait. None of the journals published in Egypt were cited or surveyed by ISI in 1990. This gives us an idea of the relevance of Arabic publications to the international monitoring of scientific output.

## Bureaucratization of Science

The professional performance of scientists and technologists depends on their creativity and motivation. The relationship between the individual, his institution and society is delicate and complex. Science is managed by peer groups and not by bureaucracies. Scientific activity is heavily dependent on access to information and to the belonging of individual scientists to invisible colleges that regulate the rapid diffusion of research information. Unless society provides the basic requirements for undertaking scientific research, the scientist is disabled and cannot participate effectively in scientific enterprise. Government is called upon to facilitate the processes of diffusion of knowledge, the provision of education and training, the encouragement of invention and innovation, and the promotion of the application of knowledge. Bureaucrats play a back-seat role in science; intelligent governments seek to harness creativity and talent, and not to deem it within their power to intervene bureaucratically in scientific matters. In general, they leave it to the scientific community to argue findings, and formulate theories and educational systems. The standards of the scientific profession are thus self-applied. Needless to say, governments influence scientific activity indirectly by providing funding for some and refusing funding for others. Here the intervention is peripheral; the allocation of funds to specific projects is generally performed by the scientists themselves, who evaluate the research proposals and the qualifications of the research workers.

In Egypt, the process of bureaucratization of S&T preceded the emergence of scientific communities. The very programme which led to the selection and dispatch of young people to study abroad in the nineteenth century was centrally decreed. The selection of students was not a reflection of the personal scientific and intellectual aptitudes of the scholars but rather based on a bureaucratic process. The post-independence educational programmes established by most Arab states were of a similar nature: the state provided scholarships to students to study abroad and the students were often selected on the basis of their loyalty to a political party. It is reasonable to expect that countries which discover a need for an increase in the number of professional and scientific manpower would pursue their objectives through some central planning. The issue is not the need to plan foreign study, but rather the manner in which students are selected and assigned courses of study. The allocation of jobs to scientific manpower returning from study abroad is generally not any more logical than the initial process of selection. Most elements of personal choice and scientific interests are usually eliminated from the selection of a foreign study programme and the later assignment of a post.

A major feature of the process of bureaucratization is the development of ministries that are responsible for higher education and scientific research. The senior staff of these ministries, despite their apparent enthusiasm, lack essential practical experience. The staff of these ministries generally subscribe wholeheartedly to rigid centralized forms of organization. These bureaucrats plan science as if it were a matter of counting tomatoes. Creativity, concepts and institutions are downgraded and reduced to vacuous arguments. The sensitivity of an intellect, the level of creativity of the individual scientist, or the particular needs of each member of the scientific community is not a subject of concern or interest to these bureaucrats. The educational systems that were to transform the Arab world have never been subjected to critical analyses and appraisals. Alternative approaches are rarely discussed with any thoroughness, nor are the experiences of other cultures compared or examined.

Not surprisingly, the only independent 'external' inputs have been made by a small number of bureaucrats in a few UN organizations—such as UNESCO—or the World Bank. Very few of the consultants working in these organizations have any meaningful intellectual experience in industrial or developing countries. Furthermore, their contributions usually support the belief prevalent in central planning and the importance of linkages to the top decision maker. Governments and regional Arab conferences discussed reforms. UNESCO sponsored the Conference on Science and Technology Policies in the Arab States (CASTARAB) in Rabat in 1976. It was shown elsewhere that CASTARAB avoided serious discussion of the important issues and concentrated instead on the issuance of the pompous and vacuous Rabat Declaration (Zahlan, 1980). None of the modest recommendations made at the CASTARAB conference were implemented. The follow-up conferences failed to materialize. Similarly, ALECSO sponsored three different programmes of study on education, culture and science in the Arab world. In each case, 'responsible' and 'competent' scholars, officials and scientists formed the committees designated to undertake the studies. The latest exercise of this nature was the one sponsored by ALECSO leading to the preparation of an Arab Strategy in Science. All these bureaucratic attempts have failed to deliver useful results.

The process of bureaucratization of the management of scientific communities and institutions as practised in the Arab countries has resulted in a number of bizarre patterns of behaviour. Two examples may be cited to illustrate this point. First, one of the characteristics of scientific activity is that information circulates freely. One of the consequences of the process of bureaucratization is control over the process of circulation. Second, often a research institute produces nothing worth publishing; in some cases the 'research' findings are of such a local character that there would be few periodicals interested in publishing these findings. Judging from a survey of the journals published by the colleges of science and engineering of various Arab universities, it is unlikely that the papers that they publish are of scientific relevance or importance.

## Conclusion

The condition of the persistent underdevelopment of Egypt and the rest of the Arab countries is not due to the lack of access to scientific knowledge, nor is it due to a shortage of scientists and technologists. The abundance of scientific and technical manpower, their under-utilization and the resulting brain drain confirm the importance of relevant economic and technology policies.

A second notable feature is that the availability of massive financial resources is not in itself a positive factor. During the past twenty years, the Arab states have had access to considerable financial resources. Yet, these have led to negative developments. For example, between 1981 and 1991, the Arab countries invested some US $1,000 billion in their Gross Fixed Capital Formation—these investments have resulted in a decline of their GNPs of more than 20 per cent at current prices.

The absence of an adequate and serious policy analysis makes it difficult for political leaderships to draw the correct conclusions from experiences. Nationalist historians have attributed the failure to overcome underdevelopment due to the intervention of imperial forces. I argue here that the main cause for the persistence of underdevelopment in Egypt is inappropriate S&T policies. The prolonged adoption of the technology dependent turnkey approach has brought about considerable damage to the economies of the Arab countries (Zahlan, 1990). During the past thirty years, most Arab governments have only 'modernized' Muhammad Ali's invention of total technological dependence by deepening the extent of dependence.

# Annexure

## The National Research Centre

The National Research Centre (NRC) is the largest research centre in Egypt. It has fifteen divisions, of which the following illustrate its main activities:

1. *Chemical Industries*: Paper and cellulose, tanning materials, protein chemistry, polymers and pigments, chemistry of pesticides, glass and refractories, building materials.
2. *Pharmaceutical Industries*: Therapeutical chemistry, chemistry of natural and microbial products.
3. *Textile Industries*: Dyeing, printing and textile auxiliaries, spinning and weaving, pre-treatment and finishing of cellulosic fibres, and protein and synthetic fibres.
4. *Food Industries and Nutrition*.
5. *Agriculture and Biology*: Botany, pests and plant protection, soil and water use, animal reproduction, parasites and animal diseases, agricultural economy.
6. *Engineering*: Solar energy, chemical and mechanical engineering, pilot plant operations.
7. *Medical Sciences*: Pharmacology, hormones, community medicine, child health.

## Notes

1. About the research activities of the NRC see annexure.
2. For a detailed account of the report presented by this Committee, see ALECSO (1989).

## References

**Ahmar, Salah al-, Akram Nasser, Muwafak Da'aboul** and **Munzer Hindawi** (1987). 'Arab Scientific Output' (mimeo.). Damascus: Strategy Committee.

**ALECSO** (1981). *Arabic Periodicals* (in Arabic). Tunis: ALECSO.

———. (1989). *A Strategy for the Development of Science and Technology in the Arab Nations: The General Report and the Sectoral Strategies* (in Arabic). Beirut: The Centre for Arab Unity Studies.

**ASRT** (1990a). *History of the Scientific Movement in Modern Egypt* (8 volumes in Arabic). Cairo: ASRT.

———. (1990b). *Science and Technology Development in Egypt: Ten Years Review and Outlook, 1982–1992*. Cairo: ASRT.

**Bernal, M.** (1987). *Black Athena: The Afroasiatic Roots of Classical Civilisation, Volume 1: The Fabrication of Ancient Greece, 1785–1985*. London: Free Association Books.

**Davis, E.** (1983). *Challenging Colonialism: Bank Misr and Egyptian Industrialisation, 1920–1941*. Princeton: Princeton University Press.

**El-Nockrashy, A.S.** (1993). *A Case Study on National System for Productive R&D Management: The Science and Cooperation Program*. Cairo: ASRT.

**El-Nockrashy, A.S., Osman Galal** and **Jay Davenport** (1987). 'More and Better Food: An Egyptian Demonstration Project'. Unpublished Report. Cairo: ASRT and Washington: The National Research Council.

**Hubaysh, Ali Ali** (1992). *Absorption of Technology and Contemporary Challenges* (in Arabic). Cairo: ASRT.

**Sabet, Adel** (1969). 'UAR Commitments to Science and Technology', in C. Nader and A.B. Zahlan. *Science and Technology in Developing Countries*. London: Cambridge University Press.

**Zahlan, A.B.** (1980). *Science and Science Policy in the Arab World*. London: Croom Helm.

———. (1990). *Future Manpower Needs of the Arab World* (in Arabic). Amman: Arab Thought Forum.

**Zahlan, A.B.** and **Rosemarie, Said Zahlan** (eds.) (1978). *Technology Transfer and Change in the Arab World*. Oxford: Pergamon Press.

**Ziadat, Adel A.** (1986). *Western Science in the Arab World: The Impact of Darwinism, 1860–1930*. London: Macmillan.

# 4 Kenya: Crisis in the Scientific Community

**Thomas Owen Eisemon** and **Charles H. Davis**

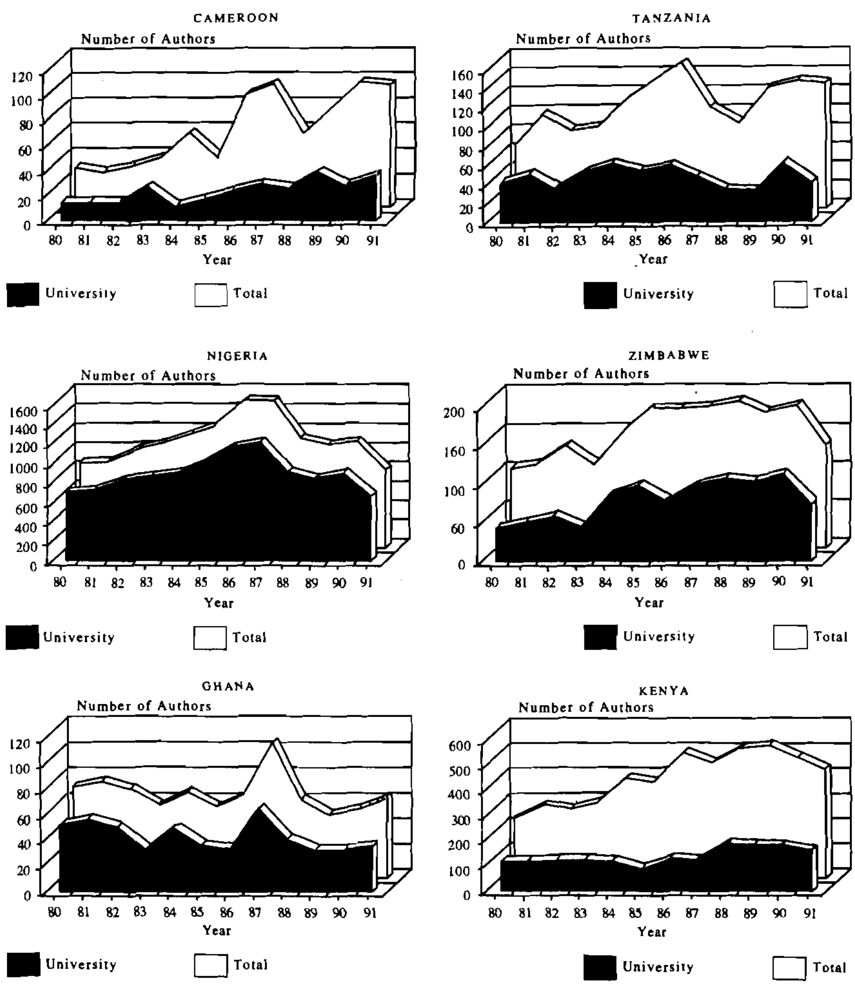
There are multiple indications that African scientific communities are in crisis, a consequence of the lack of support to infrastructure for scientific training and research. For Sub-Saharan Africa as a whole, research and development expenditures remained very low (on an average less than a third of 1 per cent of GNP in the mid-1980s) before economic conditions significantly worsened (Eisemon and Davis, 1992). Government research budgets, the source of almost all national research investments, have declined in real terms in majority of the Sub-Saharan African countries.

In Africa's public universities, the locus of most scientific training, per student expenditures (adjusted for inflation) declined from US $6,300 to US $1,500 between 1980 and 1988 (Salmi, 1991). This has occurred in conjunction with rising enrollments, resulting in severe overcrowding and straining of limited instructional resources. A high repetition rate is one consequence. Instruction in the natural and applied sciences, and engineering has been hit particularly hard by the crisis in African higher education. Between 1980 and 1989, undergraduate and postgraduate enrollments in the natural sciences fell in absolute terms as did postgraduate enrollments in agriculture in the African countries for which time series data is available (UNESCO, 1991).

The crisis in African universities and scientific institutions in the late 1980s has depressed levels of research activity and slowed the production of mainstream scientific research. Recent surveys of the number of scientific authors in African countries publishing in the most influential international scientific journals monitored by the Institute for Scientific Information (ISI) showed that, for many countries, scientific output in terms of the volume of papers and number of scientific authors increased slowly in the early 1980s, reached a peak in mid-decade, and declined (sharply, in some cases) thereafter (Eisemon and Davis, 1991, 1992).

Data for six of Africa's largest scientific communities is presented in Figure 4.1. The large annual fluctuation in the number of publishing scientists is a symptom of institutional and financial instabilities in African scientific communities, and of the relatively small size of these communities. The number of mainstream scientific authors has declined in all the countries

**FIGURE 4.1**
**Number of Mainstream Scientist Authors in Selected African Countries, 1980-1991**



except Ghana, where some recovery has taken place in the past few years, though numbers are still well below the 1988 level. In Nigeria, Africa's largest scientific community after South Africa, the number of scientific authors has declined by almost half, from more than 1,500 in the late 1980s to about 800 today. Generally, the decline in university producers mirrors the situation in the national scientific community, except in Cameroon, where the number of university authors has increased slightly since 1989 despite the decline in the total number of scientific authors.

This paper examines the crisis in Kenya's scientific community—Sub-Saharan Africa's third largest after South Africa and Nigeria—with a focus on the declining output of agricultural research. The present importance of agriculture and the eventual importance of non-agricultural income generating activities to Kenya cannot be overemphasized. Over 80 per cent of Kenyans presently earn their living from the 17 per cent of Kenyan territory that is classified as high potential agricultural land. Agriculture accounts for 35 per cent of Kenya's GDP, 60 per cent of Kenya's total exports, and 80 per cent of Kenya's wage and non-wage employment. Major exports include coffee, tea, refined petroleum products, hides and skins, soda ash, beans and peas, pyrethrum and pineapples.

Kenya's climate and pattern of precipitation are such that around 80 per cent of the country is arid, semi-arid or otherwise of low agricultural potential. Furthermore, Kenya's population of approximately 25 million people has one of the fastest national growth rates in the world—about 3.3 per cent annually. By the turn of the century, the population will rise to an estimated 34 million. More than 60 per cent of Kenyans are minors. In other words, Kenya has a young, rapidly growing population and a highly inelastic resource base upon which to expand agricultural production. The Government of Kenya recognizes that the major challenges facing the country are the generation of employment, and the maintenance of social services and infrastructure in the face of rapid population growth and high unemployment (Omuse, 1991; World Bank, 1986).

Historically, agriculture was the axis of development of Kenya's scientific community. As was the case in many other African countries, agricultural research was primarily carried out in government scientific institutions. Since independence, agriculture has received high priority in Kenya's scientific and educational planning, reflecting the importance of the agricultural sector in terms of employment and exports. However, an important difference between Kenya and other African countries is the greater amount of foreign funding of scientific training and research (Eisemon, 1986) and the relatively larger number of international scientific institutions located in the country (Eisemon et al., 1985).

We begin with a brief account of the development of scientific institutions in the colonial and independence periods. This is followed by an analysis of the institutional distribution of national research production in the 1980s and early 1990s. We show that the declining volume of mainstream scientific activity is evident in most institutional sectors of research production, including many international scientific institutions. A more comprehensive analysis of all kinds of agricultural research production reveals a somewhat similar pattern. The problems of Kenyan universities, government scientific institutions and some international scientific institutions are then discussed. The concluding section considers the prospects for rehabilitating Kenya's infrastructure for scientific training and research.

## The Development of Science and Higher Education in Kenya: Colonial Legacies

In Kenya, scientific institutions were founded in the first decade of this century coincident with the European settlement of the Central Highlands. An experimental station for livestock research was established in 1903 at Naivasha and within a few years the colonial government created a Department of Veterinary Services to coordinate these activities. The European population was less than 1,000 when the government began directing efforts to facilitate the transplantation of European modes of agricultural production in order to encourage immigration (Eisemon, 1982).

Initially, agricultural production native to Africa accounted for most of Kenya's exports. After 1912, local production fell as peasants were pressed into wage labour (Leys, 1975). A dual agricultural economy emerged: a plantation economy oriented to supplying metropolitan markets supported by a network of government scientific institutions and services, and a subsistence economy whose scientific needs were largely ignored.

In the interval between the two World Wars, a territorial and some subregional infrastructure for scientific research and training was developed. The nearly abandoned Amani Research Institute (Tanzania), which had been established by Germany before the First World War, was resurrected in 1927 as the site for the first inter-territorial agricultural research institution serving the East African region. In the 1930s, the Central Veterinary Research Institute (attached to Kenya's Department of Veterinary Services) was established outside Nairobi. Its activities were regional in scope and its research programme jointly funded by the three colonial governments. To staff the territorial and inter-territorial scientific services and institutes with technicians, the training school at Makerere, in Uganda, was slowly transformed from 1924 into a regional college, offering teacher education and studies in medicine, agriculture and veterinary science.

After the Second World War, Britain, like France, began to increase its investments in research in Africa. The British government's Colonial Development and Welfare Act 1940, which was regarded as a more or less comprehensive programme of development assistance, initially allocated about 10 per cent of its funds for colonial R&D. A colonial research system, complete with specialized research councils permitting central coordination was built around new or rehabilitated colonial and metropolitan scientific institutions. Three principles guided the development of scientific facilities in British colonies in Africa: (*a*) the facilities should be in the colonies rather than in the metropole, (*b*) research should be organized on a subregional rather than on a territorial basis, and (*c*) colonial administrations should share in supporting the costs of research facilities and eventually bear complete responsibility for them (Jeffries, 1964).

Central organization of research in British East Africa had been proposed as early as the 1920s, but the metropolitan disfavour of schemes for the union of East African territories led to the development of technical services on a territorial rather than on a subregional basis, with the exception of agricultural research and meteorological services. During the War, however, it was decided to create a limited form of functional association among the East African territories, and the resulting East African High Commission (1948) provided the inter-territorial coordinating machinery under which about fifteen subregional scientific research organizations or technical services were established by 1951. These included research organizations or technical services for agriculture and forestry, veterinary medicine, fisheries, tropical pesticides, viruses, tsetse and trypanosomiasis, malaria, leprosy, locusts, industry, statistics, and health and medicine (Worthington, 1957; Beck, 1973). Research institutions in East Africa received the lion's share of colonial research grants between 1940 and 1960 (about 39 per cent of the total, or more than twice as much as any other colonial subregion [Davis, 1982]). By the 1960s, East Africa had the most experienced and successful infrastructure for subregional scientific and technical work on the continent, conducted under the auspices of an economic grouping that appeared for a time to be one of the most successful subregional integration schemes in the developing world. About one-sixth of all research organizations in Africa in 1960 were in British East Africa, and about half of these were subregional cooperative organizations (Mazzeo, 1976).

A policy structure for managing science on a subregional basis emerged after 1945. Inter-territorial research was intended to complement rather than replace work undertaken by territorial research stations. To ensure complementarity, a policy advisory system was developed that brought together representatives of local technical departments, British scientists and representatives of each of the territorial departments. The East African Industrial Research Organization, created under wartime conditions to foster self-sufficiency, provided the model for the formation of the East African Agricultural and Fisheries Research Council in 1947. The Council advised the East African High Commission and the Central Legislative Assembly on the needs of the research system, established funding priorities and allocated projects to territorial and inter-territorial institutes and services. Councils were also established to coordinate health and industrial research. This mode of organization of research was regarded by metropolitan authorities as an experiment, with potential applicability in other colonial subregions.

Agricultural sciences were always the priority of the colonial governments in British East Africa. In the mid-1950s, agriculture-related institutes and services received about two-thirds of the recurrent funding for all East African scientific institutions (Worthington, 1957). Most agricultural research carried out in these institutions addressed the needs of the settler community. 'Compared to other parts of the tropical world', Cooper observed, '[East] Africa was not an area where it can be said that research has been neglected. Its understandable limitation', he added, 'was that it produced a profitable technology for export crops but not for food crops' (Cooper, 1970: 2).

The pace of Africanization of the subregional research services was not rapid. According to the 1961 Frazer Report, commissioned to provide advice on the organization of research in East Africa, of the eighty subregional research officers then in service, seventy-eight were expatriates, one was Asian and one was African (cited in Davis, 1982). In the late 1960s, about 80 per cent of the research officers were expatriates (Bohnet and Reichelt, 1972). Commented Mazzeo (1976: 99) on this state of affairs:

> . . . even admitting that in the past it must have been difficult to find suitable candidates, the slow pace of Africanization in this field [i.e., research] reveals a lack of interest in the matter on the part of donors. Until the late 1960s, practically no serious and systematic effort was undertaken to train counterpart researchers.

The recruitment of young expatriate researchers reinforced the colonial appearance of the subregional research services in the decade after independence, and led to the criticism that 'many of the younger expatriate research workers . . .use the East African research institutions as a stepping stone or ladder to some higher academic status after they have obtained their doctorate degrees at the expense of East Africa' (Chagula, 1968: 10). East African scientists, grouped under the East African Academy, resented their exclusion from the subregional research policy making process (Gruhn, 1967).

If the quality and quantity of research institutions in East Africa promised a hopeful future for scientific research in the region, the slowness with which scientific training institutions were developing did not. In the imperial division of scientific labour, scientific training was the responsibility of the metropole. In 1937, the de la Warr Commission proposed that Makerere become a university college where students could study for external degrees granted by the University of London. The Commission urged that 'the most promising students should be given an opportunity of working as assistants, or of conducting inquiries under guidance, at places such as [the research stations at] Amani and Nairobi' (Secretary of State for the Colonies, 1937: 112). Makerere was eventually established as a university college in 1949. In the same year, the colonial government in Kenya gave approval for establishing a new vocational and technical institution offering diploma programmes in various applied scientific fields, including agriculture and veterinary medicine.

By the late 1950s, except for Uganda, East Africa hardly possessed any capacity to provide advanced training to the indigenous African population on the scale that would soon be needed. The Royal Technical College in Nairobi attained university college status in 1960, only three years before independence. Its enrollment was less than 600 students (Eisemon, 1982). Another university college at Dar es Salaam was still under construction. At the time of independence, the three colleges were federated into the University of East Africa.

The network of national and regional scientific institutions created during the colonial period continued to function for many years after independence under the auspices of the East African Community and its Common Services Organization. Like the University of East Africa, these institutions benefited from the patronage of bilateral donor agencies such as USAID and the British Overseas Development Agency. In the 1960s, foreign assistance abounded—about one-third to one-half of East African research budgets were foreign assisted (Mazzeo, 1976). However, foreign support for the recurrent costs of East African scientific institutions declined after 1970, and the rate of growth of the scientific and technical research institutions declined compared to other East African common services—an indication of partner states' preference to shift support to national research institutions and universities. Also, donor involvement in these institutions supported a broadening of their research programmes and extension work to better address the needs of small farmers. This, of course, required fundamental changes in their activities, staffing and historic missions.

## Expanding the Infrastructure for Scientific Training and Research

At the end of the 1960s, donors began to increase their investments in the nascent network of International Agricultural Research Centres (IARCs); the first in Africa being the International Institute for Tropical Agriculture in 1967 located in Ibadan, Nigeria. In 1971, FAO, UNDP, the World Bank, the Rockefeller and Ford Foundations, USAID and the British Overseas Development Agency organized the Consultative Group for International Agricultural Research (CGIAR) to support development of new varieties and production techniques of plants to increase yields of basic food crops for transfer to national research institutions. Four international research centres were established in Africa in the 1970s, two of them with headquarters in Kenya—the International Laboratory for Research on Animal Diseases (ILRAD) in 1974 and the International Council for Research on Agro-Forestry (ICRAF) in 1977. A third centre, the International Livestock Centre for Africa (ILCA), was originally established in Ethiopia but expanded its operations to Kenya after 1980. In addition, certain highly specialized African scientific institutions received regular support from external donors. The most important of these was the International Centre for Insect Physiology and Ecology (ICIPE) set up in 1970, which carries out research on ecologically sustainable pest management technologies.

In the 1970s, international research institutions were the fastest-growing institutional sector of mainstream science production in Sub-Saharan Africa (Davis, 1983a). The international institutes and centres became a favoured conduit for donor investment in agricultural research in Kenya, the host country for one-quarter of all research in Sub-Saharan Africa produced by the IARCs and other United Nations organizations in the 1970s (ibid.).

The dissolution of the University of East Africa and founding of national universities in 1970 foreshadowed the collapse of the East African Community in the late 1970s. The underlying causes were similar and complex. Regionalism had a long and controversial history. From an imperial standpoint, the benefits of rationalizing the use of the limited resources available for colonial development seemed obvious. However, regionalism produced frequent conflicts between colonial governments as well as with the vocal European settler community in Kenya, which felt that it had special needs and hoped for eventual dominion status (Bennett, 1978).

Regionalism enjoyed nominal support from the African and Asian populations, and was embraced by Kenyatta, Nyerere and Obote at independence. Furthermore, by the early 1970s, significant progress had been made in recruiting African scientists into inter-state research organizations. By 1973, about half the total number of researchers at the six major subregional research organizations were East Africans (Mazzeo, 1976). However, the unequal development of the three territories made harmonization of scientific, educational and economic policies difficult. A study of the research activities undertaken by the largest of the subregional research organizations, the East African Agriculture and Forestry Research Organization (EAAFRO), found that although most of the EAAFRO's high priority research projects were intended to address subregional needs, most did not correspond to national development priorities as expressed in the national development plans to the three member states (Schlie and Rubenstein 1974). Additionally, most of EAAFRO's lower priority research activities were biased towards Kenyan interests. The scientific services offered by EAAFRO were, by virtue of their location in Kenya, more accessible to users in Kenya than in Uganda or Tanzania. Subregional research conducted by semi-private research organizations such as the Tea Research Foundation or the Coffee Research Foundation was much more directly related to the stated priorities of the three East African countries than was most research conducted under EAAFRO auspices (Schlie, 1974). In other words, the largest research organization in one of the best established inter-state research systems in Africa was conducting research that was either not of primary interest to the partner states or that was not equally accessible to them all.

The regional scientific institutions and services persisted for several years until disputes over the financing of the East African Community and the benefits each country derived prompted Kenya to unilaterally dissolve the Community in 1977 and seize a large share of its assets. The government acted quickly to repatriate the science policy making and coordinating structures of the Community. An S&T statute was passed that year creating a national science planning structure and the government subsequently amended it to permit the establishment of national medical, agricultural and industrial research organizations to coordinate the activities of public scientific institutions.

The Kenya Agricultural Research Institute (KARI) inherited from the Community the facilitates at Muguga and responsibilities for its research programmes on animal health, animal production, forestry and crops. Between 1978 and 1982, the Institute's scientific staff rapidly increased as did the staff of other scientific institutions. KARI did not begin to coordinate the activities of units attached to government agricultural and livestock departments until much later. A national agricultural research strategy was not developed until 1987 when, with support from the World Bank and USAID, a project to strengthen the capacity of KARI was approved. Administrative responsibility for the programmes and scientific personnel of the relevant ministries were transferred to KARI. The Institute also acquired responsibility for linking public and private agricultural research as well as for ensuring that the agricultural training institutions responded to the needs of the agricultural research system. Nevertheless, intra-governmental conflicts continued to affect KARI. Between 1987 and 1990, ministerial responsibility for the research institute changed four times. KARI is now attached to the Ministry of Research, Science and Technology.

The regional higher education system suffered a similar fate. Early on, the imperative of expanding and Africanizing public bureaucracies strained relations among the newly independent states, leading to duplication of programmes offered by the University colleges which the University was powerless to prevent. The acts creating the new national universities resolved previous ambiguities. They explicitly subordinated the institutions to the state. Human resource development required government financial and administrative control of higher education institutions.

University enrollments, which grew modestly for almost two decades after independence, greatly expanded in the 1980s. The number of students admitted annually for degree studies increased from about 2,500 in the early 1980s to more than 21,000 by 1990.[1] The number of universities proliferated to accommodate this growth. Kenya's second university, Moi University, was established in 1984 to offer courses in applied scientific fields including forestry and environmental sciences. The next year (1985), Kenyatta University College, a constituent institution of the University of Nairobi offering teacher education programmes, was elevated to university status. The following year, Egerton College, which offered diploma programmes in agriculture since 1939, was made a university college. It became a university in 1987. Two more diploma granting institutions were transformed into university colleges—Jomo Kenyatta University College of Agriculture and Technology became a constituent college of Kenyatta University in 1988 and Maseno University College was affiliated to Moi University in 1990. Total university enrollment has now reached about 40,000 students in 1992–1993.

Since independence, foreign donors have played a crucial role in financing African scientific research and in delivering the technical inputs required by development projects. In the 1970s, one-seventh of all mainstream scientific authors in Sub-Saharan Africa were based in bilateral or multilateral institutions supported largely by foreign funds (Davis, 1983a). In 1973, nearly 95 per cent of agricultural research publications from Francophone Africa were authored by foreign expatriates (Bennell and Thorpe, 1987). Kenya has one of the most international scientific communities in Africa. It has been estimated that the ratio of foreign to national research support, excluding funding for capital and recurrent costs, is about 10:1 in Kenya (Eisemon, 1986). Kenya also traditionally provides a congenial base for research in Africa by expatriate researchers. About 40 per cent of the 1,762 researchers not affiliated with accredited research institutions and whose projects received clearance from the Government of Kenya between 1983 and 1989 were non-Kenyans (Majisu, 1992). Nkinyangi (1983) found that the most frequent subjects for research clearance requests were economics, education, zoology, pre-history, sociology, anthropology, geology, rural development and history.

Kenya is also home to a number of international African scientific associations, the most prominent of which is the African Academy of Sciences (AAS) established in 1986 with well-known Kenyan entomologist Prof. Thomas R. Odhiambo as its first president. Activities of the AAS include establishment of electronic communication networks among African research institutions, preparation of profiles of African scientists, awarding of scientific prizes, publication of scholarly and popular material, involvement in policy dialogue, and management of capacity-building and grants programmes (AAS, 1989, 1992).

## Production of Mainstream and Non-mainstream Research

Most of the scientific and technical literature produced in developing countries is not captured in international databases. However, strong evidence exists that national ability to produce 'mainstream' scientific literature is positively and perhaps functionally related to national ability to produce other, less internationally-visible kinds of scientific literature that generally bears on research applications (Davis and Eisemon, 1989). In the case of Africa, the well-documented erosion in many countries of the capacity to produce mainstream research literature in universities is paralleled by a reduction in the capacity to produce agricultural research literature in public sector research organizations (Bennell and Thorpe, 1987).

The number of scientists based in Kenya producing internationally influential research has not substantially increased since the late 1980s. Moreover, between 1989 and 1991 the number of mainstream authors declined by 16 per cent. The decline is evident in almost all important sectors of institutional production (Table 4.1). University authors of mainstream scientific papers accounted for 25 per cent of all Kenyan mainstream authors in 1991. Their numbers peaked between 1988 and 1990, then declined by 15 per cent. Since 1989, the number of authors affiliated with government and parastatal agricultural and veterinary/livestock research institutions has declined appreciably. In the case of those affiliated with agricultural research institutes, the number of authors has decreased by over 40 per cent between 1985–1986 and 1990–1991.[2] The number of authors affiliated with health institutes, most of which are managed by the Kenya Medical Research Institute, more than doubled between 1985 and 1988, and then declined by about 40 per cent. More remarkably, the number of scientific authors working in regional and international agricultural research institutions located in Kenya has also declined. Their number fell by 30 per cent between 1986 (the peak year) and 1991.

The staff of the small number of regional and international institutions are the most active component of Kenya's scientific community. In most years, they produce a third or more of Kenya's mainstream scientific output and represent a similar proportion of scientific authors. However, the number of scientists producing mainstream research who work at the three constituent centres of the CGIAR system—ILCA, ILRAD and ICRAF—dropped by 35 per cent between 1987 and 1991 (Table 4.2). The number of scientific authors at ICIPE, an indigenous regional research institution with a history of affiliation with the CGIAR group, declined by almost half (48 per cent) in the same period.

Only a small proportion of the total scientific output of Kenya's scientific community is captured by ISI's survey of highly cited science. The ISI database is particularly weak in applied scientific fields (Davis and Eisemon,

TABLE 4.1
**Kenyan Mainstream Scientific Authors by Institutional Affiliation, 1985–91**

| *Year* | *Universities* | *Agricultural Institutes* | *Veterinary/ Livestock Institutes* | *Health Institutes* | *Regional and International Institutes* |
|---|---|---|---|---|---|
| 1985 | 94 | 32 | 27 | 69 | 151 |
| 1986 | 154 | 37 | 22 | 76 | 195 |
| 1987 | 142 | 47 | 14 | 58 | 189 |
| 1988 | 187 | 17 | 26 | 148 | 129 |
| 1989 | 181 | 29 | 35 | 124 | 144 |
| 1990 | 183 | 26 | 20 | 84 | 142 |
| 1991 | 159 | 15 | 32 | 93 | 132 |

Source: *Corporate Index*, Philadelphia: ISI.

TABLE 4.2
**Mainstream Scientific Authors by Major International and Regional Institutions, 1987–91**

| *Year* | *ILCA and ICRAF* | *ICIPE* |
|---|---|---|
| 1987 | 92 | 56 |
| 1988 | 57 | 27 |
| 1989 | 59 | 31 |
| 1990 | 60 | 34 |
| 1991 | 60 | 29 |

Source: *Corporate Index*, Philadelphia: ISI.

1989), especially in the coverage of research in agricultural sciences, much of which is published in journals intended for small speciality groups that generate relatively few citations or are issued in other research formats such as technical reports. The Agricultural Research Information System (AGRIS) database is more comprehensive (thus, less selective), and includes technical reports and other grey literature in addition to journal articles.

We searched the AGRIS database for documents authored between 1985 and 1991 by researchers affiliated to scientific institutions in Kenya. More than five hundred documents were located, with nearly half (43 per cent) the articles in local (9 per cent) or international journals (34 per cent). More than a quarter (27 per cent) of the documents were technical reports. An analysis of the authorship of these documents is given in Table 4.3.

The findings are generally consistent with those presented earlier. The output of public scie .tific institutions, and to a less extent the universities, has declined over the last three years. The sharpest decline has been experienced in the agricultural research institute sector, where the output of research documents declined by 66 per cent between 1985–1986 and 1990–1991. However, the output of agricultural research literature of

TABLE 4.3
Kenyan Authors of Agricultural Literature by Institutional Affiliation, 1985–91

| *Year* | *Universities* | *Agricultural Institutions* | *Veterinary/ Livestock Institutions* | *Health Institutions* | *Regional and International Institutions* |
|---|---|---|---|---|---|
| 1985 | 13 | 27 | 8 | 0 | 9 |
| 1986 | 8 | 64 | 6 | 0 | 25 |
| 1987 | 6 | 39 | 1 | 1 | 3 |
| 1988 | 9 | 45 | 4 | 2 | 4 |
| 1989 | 20 | 46 | 6 | 4 | 17 |
| 1990 | 15 | 20 | 5 | – | 42 |
| 1991 | 11 | 11 | 4 | – | 59 |

Source: AGRIS index.

scientists in regional and international institutions located in Kenya increased by 48 per cent between 1985–1986 and 1990–1991. Most (61 per cent) of this output was in the form of articles that appeared in international journals which did not have high citation visibility.

In sum, this data shows largely stagnant or declining research activity in the major institutional components of Kenya's research system. Kenyan universities and government scientific institutions are carrying out less research than previously. The situation regarding regional and international institutions located in the country is less clear. These institutions are producing a declining volume of internationally influential research, but appear to have increased their production of research literature published internationally. Overall, fewer scientists in Kenya are producing high impact research. The production of less influential research has also diminished significantly in the universities and national agricultural research institutions. The next section examines some of the circumstances that have led to this situation.

## Crisis in the Research System

### The Universities

Since independence, the university system has been the fastest growing component of Kenya's scientific community. In the late 1970s and 1980s, particularly after the collapse of the East African Community and its network of regional scientific institutions, the Kenyan university sector became increasingly important as a locus of research activity. In the mid-1980s, it accounted for about a third of the country's R&D personnel, perhaps a fifth of national R&D expenditures and a fourth of its mainstream scientific output (Eisemon and Davis, 1992). Postgraduate enrollments rapidly increased to 20 per cent of total university enrollments (ibid.). Expansion of postgraduate programmes was accelerated by the proliferation of universities whose needs for staff development could not be satisfied by foreign training alone.

As in many other African and Asian countries in which universities are a growth sector in a relatively slowly expanding scientific community, the expansion of higher education in Kenya is prompted by enrollment increases at the secondary level. While university expansion may be guided by a desire to achieve a greater measure of self-reliance in scientific training and research, it is also a consequence of popular pressures for increasing admissions to institutions of higher education in response to the increasing number of students eligible for entry.

The proliferation of universities in Kenya has not kept pace with the increase in demand for higher education. In 1988, only about one-quarter of the 13,800 qualified 'A' level leavers were initially to be placed in Kenyan universities; a public debate and numerous appeals to high political figures persuaded the government to increase the intake to 7,000 students (King, 1989). Dramatic upward revisions of university intake, well above those recommended by the universities, became commonplace in the late 1980s as the 8 + 4 + 4 reform of the organization of primary and secondary education introduced in 1986 was fully implemented. By 1991, university education was consuming 35 per cent of the recurrent government budget and almost 60 per cent of the development budget (Omari, 1992)! If it is to accommodate qualified secondary school-leavers with places in university, Kenya could be facing a ten-fold increase in university enrollments between 1985 and 2000 (King, 1989).

Yet, the quality of university education is rapidly deteriorating. Per student expenditures declined by 30 per cent between 1987 and 1991.[3] University instructional and residential facilities are being strained beyond capacity. This, in turn, has exacerbated student unrest which became more frequent, resulting in university closures. Disturbances were precipitated in 1992 by the government's efforts to introduce tuition fees and moderate enrollment increases at the urging of international financial institutions. Any benefits that will be derived from these measures are not likely to be realized for a long time as the funds obtained from tuition fees will be offset by a highly subsidized universal student loan scheme. The frequent closure of the university system has stacked up several batches of university entrants. Kenya has experienced substantial rises in student failure and repeat rates as institutions attempt to cope with vastly overcrowded teaching situations. At Kenyatta University, the proportion of first-year students failing or repeating increased by 57 per cent after the double intake of 1987 (King, 1989).

Like Nigeria, Malaysia and Indonesia, Kenya had a promising economic future in the 1970s based on rising commodity and resource prices. Changes in the economic fortunes in the 1980s did not lead to contraction of university enrollments, despite the appearance of graduate unemployment in all fields. The emphasis was largely on quantitative expansion. Not until 1970 were postgraduate programmes developed at the University of Nairobi (Eisemon, 1982). Throughout the colonial period and in the first few years of independence, the training of undergraduates was the primary, and indeed only, mission of higher education. Any research training Kenya required was carried out in the metropolitan country, and applied scientific research was the responsibility of government scientific institutions established for this purpose.

In Kenya, as in most African countries, the establishment of postgraduate programmes generally arose from the need to Africanize universities and national scientific institutions to reduce reliance on expatriate staff and donor assistance for university development. This was made the first task of the University of Nairobi when the donor-supported University of East Africa was dissolved in 1970. Postgraduate programmes were hurriedly put in place, staffed and intake sanctioned to identify and develop future academics. The first Kenyan professor was appointed in 1963, the year the University of East Africa was founded and Kenya attained independence, and when tokenism caused little embarrassment. By 1977–1978, almost half of the academic positions at the university were held by Africans, including Kenyans and Ugandan expatriates, as was the case in most African countries by the late 1970s (World Bank, 1988).

In Kenya and elsewhere, much of the progress in Africanization was achieved through foreign training (Eisemon, 1982). At the University of Nairobi and most other African universities postgraduate programmes, except those in fields in which a postgraduate diploma or degree is a professional qualification, are intended for individuals holding academic appointments who frequently have substantial teaching, supervisory and advisory responsibilities and pursue their studies on a part-time basis. Universities in Kenya and elsewhere in Africa often depend on postgraduates to staff undergraduate courses. At Kenyatta University and the University of Nairobi, tutorial fellows (usually doctoral students) teach up to four undergraduate courses per term. This involves a substantial time commitment which is much higher than that normally permitted for postgraduate teaching and research assistants in major North American universities. Senior academic staff, even professors, often teach up to four courses as well, leaving little time for supervising postgraduate students. The time needed to produce graduates is often very long, particularly for doctoral students whose dissertations must be externally examined. Opportunities for postgraduate training in Kenya are limited by the requirements of undergraduate programmes, which have priority. At the University of Nairobi, less than a third of the candidates for Master's courses in 1987–1988 could be enrolled because of the lack of instructional and research space.

Rapid increases in student numbers exacerbate the problem of faculty shortages. In June 1987, over one-tenth of the faculty positions at the University of Nairobi and one-half of the positions at Moi University were unfilled. Inevitably, education declines in quality in circumstances such as at Kenyatta University described by King (1989):

> There have been no tutorials since the 1987–88 academic year, despite a dramatic increase in sizes of many classes. Some faculty members have been forced to repeat the same lecture to as many as eight groups because of a shortage of lecture theatres of adequate size. In other cases, students have had to sit outside the classroom and listen to their lectures through the windows. The capacity of the library is 1500 while the enrollment has exceeded 6500. Rooms in the halls of residence originally designed for two are being occupied by as many as six students.

The allocation of scarce staff resources for postgraduate training can have detrimental implications for undergraduate programmes as well, especially in scientific and technical fields where laboratory or practical work is integral to instruction. For example, the Faculty of Agriculture at the University of Nairobi, with almost fifty senior staff, graduated only 388 students from 1971 to 1979 (Republic of Kenya, 1981). It provided postgraduate training to almost seventy students during this period, however.

In sum, research and postgraduate training are casualties of university expansion in Kenya. University laboratory and library facilities are in urgent need of rehabilitation. Staff teaching loads have increased while real incomes have decreased. Many academics must engage in income-generating 'straddling' activities in the private sector. Postgraduate students, most of whom are employed as tutorial fellows with heavy teaching responsibilities, cannot be adequately supervised, thus lengthening the time needed to complete their studies. Overall, expansion of the Kenyan system of higher education is only loosely articulated within the government strategies for the development of a modern economy.

## The Government Research Institutes

Kenya has six semi-autonomous national research institutions which were established under the 1979 Science and Technology Act. By far the largest is KARI, a national network of research centres with headquarters in Nairobi. The other government research institutes are: the Kenya Medical

Research Institute (KEMRI), the Kenya Trypanosomiasis Research Institute (KETRI), the Kenya Forestry Research Institute (KEFRI), the Kenya Marine and Fisheries Research Institute (KEMFRI), and the Kenya Industrial Research and Development Institute (KIRDI). In addition to these six so-called mission-oriented research institutions, Kenya has two 'client-centred' institutions—the Coffee Research Foundation and the Tea Research Foundation.

Like the university system, the agricultural research institutes, managed by KARI after 1979, experienced rapid expansion that the government was unable to adequately finance. New resources made available to the institutes supported the addition of scientific, technical and clerical staff, while funding for research and extension activities declined to less than 20 per cent of recurrent costs. Much of the funding made available for research is from donor sources, including the counterpart commitments necessary for leveraging these funds.[4]

Since 1986, the research facilities of the agricultural institutes have been rehabilitated and laboratories have been re-equipped. The re-organized KARI is composed of fifteen national research centres, six sub-national research centres (excluding four national centres which also have responsibilities at the sub-national level) and eleven research sub-centres. Through this institutional arrangement, KARI undertakes research on agricultural factors and commodities, livestock, soil and water management, and production problems in Kenya's various agro-ecological subregions. Several of the national research centres, such as the National Sugar Research Centre—Kibos, the National Potato Research Centre—Tigoni and the National Range Research Centre—Kiboko, have only a few professional staff: six, ten and fourteen respectively. Many of the regional research centres are even smaller, most with less than ten professional staff, and some of the sub-centres have only one or two staff.

The number of agricultural research centres has been reduced from forty-five to fifteen, the research programme has been re-focused, and the mandate and roles of the different tiers of the research system have been made more explicit. However, staffing has not been reduced and there has been no significant new investment in research and extension work, either from the government or from the donors. Moreover, KARI is still financing debts it inherited from before its restructuring and continues to be unable to obtain credit from suppliers. Its long-term financial viability remains precarious.

KARI and the five other government research institutes are funded largely through the public budget and by international donors, while the two Foundations are funded largely through a combination of sale of services and levies on producers. As Table 4.4 shows, only the Tea Research Foundation and the Coffee Research Foundation are independent of

**TABLE 4.4**
**Kenyan R&D Institutions' Sources of Research Funding, 1988–89**
*(million Kenyan Shillings)*

| *Institute* | *Government Subventions* | *Consultancies and Services* | *International Donors* | *Private Donations; Fund raising* | *Others and Miscellaneous* | *Total* |
|---|---|---|---|---|---|---|
| KARI | 14.33 | 0.63 | 9.07 | – | 0.59 | 24.10 |
| CRF | – | 0.62 | – | 3.34 | 0.58 | 4.06 |
| TRF | – | 0.12 | – | 0.50 | – | 0.63 |
| KEMRI | 4.37 | – | – | – | 0.12 | 4.39 |
| KETRI | 1.62 | – | 0.05 | – | – | 1.67 |
| KIRDI | 1.68 | – | – | – | – | 1.68 |
| KEMFRI | 1.70 | 0.01 | 0.47 | – | – | 2.12 |
| KEFRI | 2.43 | 0.01 | 0.79 | – | – | 3.23 |
| Total | 26.15 | 1.40 | 10.39 | 3.89 | 0.13 | 41.96 |

**Source:** Adapted from Omuse (1991).

government subventions; they are the only two institutions to derive income from private donations and fund raising. Also, income generated from consultancies and sale of services is an important part of their revenue stream. Of the six government research institutes, three are substantially dependent on international donors for income support: 38 per cent of KARI's income was provided by international donors in 1988–1989, 22 per cent of KEMFRI's and 25 per cent of KEFRI's.

Omuse (1991) recently reviewed five Kenyan R&D institutes to determine the needs for research capacity strengthening. His findings can be summarized as follows:

- It was frequently futile to attempt to obtain registers of the physical facilities and equipment in the institutions.
- Virtually no strategic thinking was evident concerning the actual or possible areas of competitive advantage of the institutions with respect to international R&D contracts.
- A great deal of equipment was unusable because of lack of maintenance.
- The institutions were experiencing great difficulty in obtaining foreign exchange for procurement of chemicals, journals and equipment.
- The institutions seemed to require assistance in strengthening R&D management skills, notably with respect to selection of promising young researchers for recruitment, research methodology, deployment of staff, incentive systems for researchers, and extension and outreach.

- Although the National Science Policy statement of 1980 had set the goal of 1 per cent of GDP expenditures on R&D during the Fourth Development Plan (1979–1983), the R&D/GDP ratio remained around 0.5 per cent.
- The 'mission-oriented' institutions were spending an average of 83 per cent of their budgets on salaries. During periods of fiscal constraints, the government would disburse funds for support of personnel but not for R&D. Undelivered operational funds were lost to the institutions even after the government's liquidity constraints had eased. The two 'client-oriented' institutions, that is, the coffee and tea foundations, were spending about 42 per cent of their budgets on salaries.

The high proportion of salary support within recurrent budgets is a widespread problem in East African scientific institutions (Nyiira, 1992). Similarly, the costs of teaching and administration account for nearly most of the African universities' budgets (Vitta, 1993).

## The Regional and International Scientific Institutions

Despite the high returns on investment in agricultural research in developing countries, higher than those to industrial R&D (Evenson, 1989), donor enthusiasm for investing in African agricultural research is waning. Donors' research investments in Kenya and many other African countries have simply not produced anticipated benefits. Productivity of small holders in Kenya, which grew at an impressive 5 per cent per annum in the first decade after independence, declined to 2 per cent in the late 1970s and has remained relatively stagnant since then (World Bank, 1986). Pricing policies, government interference in marketing, donor interference in agricultural research policy, under-investment in rural infrastructure, low prices paid for African commodities in international markets, outlawing of some traditional agricultural practices such as intercropping and other circumstances are responsible for the weak performance of the agricultural sector.

Donor fatigue with supporting agricultural R&D is also a factor. In recent years, multilateral and bilateral agencies like the World Bank, the International Development Research Centre and USAID have reduced their cadres of agriculture specialists and have either abolished their agriculture divisions and/or transformed them into environment divisions. Administrative restructuring has adversely affected the claims of the agricultural sector in the competition for resources, especially for agricultural research projects in Africa. Donor strategies for supporting agricultural research have also changed. A recent review of the performance of CGIAR institutions in East Africa notes:

> The philosophy has shifted from a search for quick technological fixes . . . which could be easily transferred to national agricultural research systems, to research that accepts the complexity of the research/production interface. The search is now for strategic component technologies that can be fitted to specific contexts in collaboration with the national agricultural research systems and national services (CGIAR, personal communication, 1992).

This has profound implications for the work of many of the largest and most prominent regional and international scientific institutions in Kenya. Traditionally, their research programmes have been 'science driven', resource intensive and focused on particular commodities or diseases rather than on farming systems. In addition, the effectiveness of these institutions has depended on their relationships with national agricultural research and extension systems, many of which are now in a state of collapse.

ILCA, in particular, has come under a great deal of pressure from its donor sponsors to focus on problems of strategic importance, reduce the scope of its activities, develop partnership relationships with national research systems and to devise ways to involve users in the formulation of its research programmes.[5] ILRAD is also being urged to be more 'client-driven'.

ICIPE, which failed to gain entry into the CGIAR system, is in the most precarious situation. In contrast to the majority of research centres that have been affiliated with the CGIAR system or included in it, ICIPE is an indigenous African institution. When the Kenyan entomologist Thomas R. Odhiambo published an article in *Science* in 1967 advocating the establishment of centres of excellence in developing countries, he caught the attention of a number of sympathetic North American and European scientists. This interest led to an arrangement whereby a new centre for research on tropical insect pest problems would be sponsored by a consortium of twenty academies of science (Odhiambo, 1971). ICIPE's mandate was to seek biological insect pest control methods at a time when mainstream agricultural research, including most of that sponsored by the CGIAR group, relied on chemical pesticides for pest control. ICIPE's structure was also novel. In order to foster research of international quality, leading scientists from around the world agreed to play a supervisory role in the young African institution. Under a 'Visiting Director of Research' system, around twenty foreign senior researchers were to be in residence at the Centre two or three times per year to initiate research projects and guide ICIPE's research staff, composed of young African postdoctoral scientists. By the late 1970s, ICIPE possessed a scientific staff of about forty persons and a personnel of 280. However, about 70 per cent of the unrestricted core operating budget of about US $5 million was provided by three donors: Sweden, Denmark and UNDP (ICIPE, 1980). In 1974, and again in 1979, ICIPE (sponsored by the UNDP) applied for inclusion in the

CGIAR system. Neither bid was successful, although ICIPE went to some length to modify its structure and research programme to conform to the commodity-oriented IARC model favoured by CGIAR (Davis, 1982).

In the 1980s, ICIPE expanded its research programme and staffing, and launched many new activities such as the African Regional Postgraduate Programme in Insect Science. However, ICIPE became increasingly dependent on short-term infusions of donor funding while watching its unrestricted core funding shrink from 80 per cent of total operating grants in 1985 to less than a third in 1991. This has substantially increased ICIPE's vulnerability to the changing priorities of its patrons. ICIPE is currently experiencing a financial crisis. It has been forced to finance operating costs commercially, at interest rates as high as 27 per cent annually, and is forced to drastically reduce staff and consolidate research programmes. ICIPE's long-term viability remains threatened. ICIPE has responded by reducing costs, strengthening financial accounting systems and launching initiatives to explore non-conventional sources of income generation (ICIPE, 1993).

## Conclusion

The crisis that is overtaking Kenya's scientific community has its origins in the rapid expansion of the country's scientific and educational establishments in the 1980s. Fundamental reforms will be required in the financing of science and higher education. Since the colonial period, this has been a government responsibility supplemented, in the case of agricultural research and training, by the largesse of donors. The challenge to Kenya's scientific community will be to use increasingly scarce resources more selectively and more effectively, as well as to diversify sources of financing.

Future growth of the university system will have to be brought into line with the resources available to finance expansion. That will require more autonomy for the universities in determining the level and distribution of student intake. Without significant devolution of government control of higher education, tuition fees and other financing reforms will be politically unsustainable. Public universities will continue to rely on government grants for most of their operating costs. But they must have incentives to raise private financing, and government allocations will have to be based on the varying needs and performances of the universities if quality programmes are to be protected and efficiency encouraged. At the end of 1993, the Commission for Higher Education was engaged in an exercise with Kenyan universities and institutions of higher education intended to culminate in the preparation of strategic plans for the institutions, and for the post-secondary education sector as a whole.

Important steps have been taken to reduce direct government control of scientific institutions such as KARI. Ahead lies the painful task of rationalizing these institutions. Government scientific institutions will have to shrink in number and size to increase funding for research. Private financing of government agricultural and most other scientific research is minuscule. The successful tea and coffee research institutes provide a possible model for what other government scientific institutions might become now that they have greater autonomy: public institutions whose research and extension programmes are responsive to the private constituencies which finance much of their activities.

Many of the regional and international scientific institutions located in Kenya will have to rethink their roles and missions. As donors review their assistance priorities, those institutions responsible for agricultural research will have to demonstrate their effectiveness, not just their potential value to small farmers. Like the national agricultural research systems they serve, these institutions will have to be more focused, more entrepreneurial and more responsive to users.

S&T policies in Africa have been notoriously ineffective and unrealistic. They have concentrated on problems of coordination and administration of the supply of research, and have hardly grappled with issues of innovation, demand, quality or competitiveness (Davis, 1983b; Davis et al., 1993). A recent report of the National Council for Science and Technology noted that Kenya does not have a comprehensive and integrated policy on science and technology and goes on to propose a number of initiatives, including the establishment of new R&D units within government, new S&T research institutes, diversification of financial support for S&T, clearer definition of S&T roles among institutions, better priority-setting procedures and wider consultation. Among the issues overlooked is that of innovative support infrastructure for indigenous small scale industry. The development of a vigorous small firm sector could contribute to the reduction of the unemployment and gender inequity problems in Kenya, as well as to the development of economic activity that is not completely dependent on agriculture or on other natural resources. There is clearly a need in Kenya, and elsewhere in Africa, for improved service institutions and policy frameworks that nurture the development of firms through delivery of technical support services, financial services, human resource development services, strategic planning services (perhaps at the sectoral level) and marketing services (Davis et al., 1993; see also ILO, 1993, and Kilby, 1988).

## Notes

**Acknowledgement**: Ms. Su Yuk Lam, a doctoral student in educational psychology at McGill University, Ms. Ame Stormer and Mrs. Omporn Regel, both of the World Bank, participated in the collection and analysis of some of the data reported here. Their assistance is gratefully acknowledged. The findings and conclusions presented are those of the authors and should not be attributed to their employers.

1. Ministry of Education, personal communication, 1990.

2. Because of large fluctuations in numbers from year to year, we have averaged the production of two consecutive years and calculated the difference in averages.
3. World Bank, personal communication, 1992.
4. World Bank, personal communication, 1992.
5. CGIAR, personal communication, 1992.

## References

**African Academy of Sciences** (1989). *Strategic Plan (1989–1992)*. Nairobi: Academy Science Publishers.

———. (1992). *Annual Report, 1992*. Nairobi: African Academy of Sciences.

**Beck, Ann** (1973). 'The East African Community and Regional Research in Science and Medicine'. *African Affairs*, 72(288), 300–308.

**Bennell, P.** and **P. Thorpe** (1987). 'Crop Science Research in Sub-Saharan Africa: A Bibliometric Overview'. *Agricultural Research and Extension*, 25(2), 99–123.

**Bennett, G.** (1978). *Kenya, A Political History: The Colonial Period*. Nairobi: Oxford.

**Bohnet, Michael** and **Hans Reichelt** (1972). *Applied Research and its Impact on Economic Development: The East African Case*. Munich: Weltforum Verlag.

**Chagula, W.K.** (1968). *The Economics and Politics of Higher Education and Research in East Africa*. Nairobi: East African Academy.

**Cooper, G.C.** (1970). *Agricultural Research in Tropical Africa*. Dar es Salaam: East Africa Literature Bureau.

**Davis, C.H.** (1982). 'Science For Africa: A Study of Selected Aspects of International Science Policy and Cooperation in Subsaharan Africa, 1945–1979'. Doctoral dissertation. Montréal: Université de Montréal.

———. (1983a). 'Institutional Sectors of Mainstream Science Production in Sub-Saharan Africa, 1970–1979'. *Scientometrics*, 5(3), 163–75.

———. (1983b). 'L'UNESCO et la promotion des politiques scientifiques nationales en Afrique subsaharienne, 1960–1979'. *Études internationales*, 14(4), 621–38.

**Davis, C.H.** and **T.O. Eisemon** (1989). 'Mainstream and Non-mainstream Scientific Literature in Four Asian Countries'. *Scientometrics*, 15(3–4), 215–39.

**Davis, C.H., S. Tiffin** and **F. Osotimehin** (1993). 'Developing Educational and Training Capacity in Management of Science, Technology, and Innovation in Africa'. *International Journal of Technology Management*, 9(1), 43–60.

**Eisemon, T.O.** (1982). *The Science Profession in the Third World*. New York: Praeger.

———. (1986). 'Foreign Assistance for University Development in Kenya: Too Much of a Good Thing?'. *International Journal of Educational Development*, 6, 1–13.

**Eisemon, T.O.** and **C.H. Davis** (1991). 'Can the Quality of Scientific Training and Research in Africa be Improved?'. *Minerva*, 29(1), 1–26.

———. (1992).'Universities and Scientific Research Capacity'. *Journal of Asian and African Studies*, 27(1–2), 69–94.

**Eisemon, T.O., C.H. Davis** and **E.M. Rathgeber** (1985). 'The Transplantation of Science to Anglophone and Francophone Africa'. *Science and Public Policy*, 12(4), 191–202.

**Evenson, R.** (1989). 'Human Capital and Agricultural Productivity Change', in A. Maunder and R. Valdes (eds.). *Agriculture and Governments in an Independent World*. Oxford: Oxford University.

**Gruhn, Isebill** (1967). 'Functionalism in Africa: Scientific and Technical Integration'. Unpublished Doctoral Dissertation. Berkeley: University of California–Berkeley.

ICIPE (1980). *Proposed Programme and Budget for the Biennium 1981–1982*. Nairobi: International Centre for Insect Physiology and Ecology.

———. (1993). 'Medium-Term Funding Prospects'. Governing Council Paper GCP/226/93. Nairobi: International Centre for Insect Physiology and Ecology.

**ILO** (1993). *Entrepreneurship and Small Enterprise Development in Urban and Rural Sectors in Africa*. Geneva: International Labour Office.

**Jeffries, Sir Charles** (ed.) (1964). *A Review of Colonial Research: 1940–1960*. London: HMSO.

**Kilby, Peter** (1988). 'Breaking the Entrepreneurial Bottleneck in Late-Developing Countries: Is there a Useful Role for Government?'. *Journal of Development Planning*, 18, 221–49.

**King, K.** (1989). 'An Essay on the Implications of University Expansion in Kenya'. Manuscript. Edinburgh: University of Edinburgh, Centre for African Studies.

**Leys, C.** (1975). *Underdevelopment in Kenya: The Political Economy of Neo-Colonialism*. London: Heinemann.

**Majisu, B.N.** (1992). 'Utilization of Research', in Commission for Higher Education. *Proceedings of the First National Seminar on the Teaching of Science in Kenya's Education System*. Nairobi: Commission for Higher Education.

**Mazzeo, Domenico** (1976). *Foreign Assistance and the East African Common Services During the 1960s, with Special Reference to Multilateral Contributions*. Bamberg: Difo–Druck.

**Nkinyangi, J.A.** (1983). 'Who Conducts Research in Kenya', in S. Shaeffer and J.A. Nkinyangi (eds.). *Educational Research Environments in the Developing World*. Ottawa: IDRC.

**Nyiira, Z.M.** (1992). 'Research Resources in National Research Institutions in Eastern and Southern Africa'. IDRC Manuscript Report No. 290e. Ottawa: IDRC.

**Odhiambo, Thomas R.** (1971). 'International Cooperation in the Social and Life Sciences', in *International Science Policy*. Washington, DC: United States House of Representatives, Committee on Science and Astronautics.

**Omari, I.** (1992). 'Management of Higher Education in Developing Countries: The Relationship between the Government and Higher Education in Kenya'. Paper presented to the UNESCO Institute for Educational Planning Seminar on Improving University Management, Paris, November.

**Omuse, John K.** (1991). 'Strengthening Research Capability'. Unpublished Report. Nairobi: The International Development Research Centre.

**Rathgeber, E.M.** (1982). 'The Transfer of Paradigms of Medical Knowledge and Research to Kenya'. Ph.D. dissertation, State University of New York at Buffalo.

**Republic of Kenya** (1981). *Second University in Kenya*. Nairobi: Government Printer.

**Salmi, J.** (1991). 'Perspectives on the Financing of Higher Education'. PHREE Background Paper. Washington, DC: The World Bank.

**Schlie, T.W.** and **A.H. Rubenstein** (1974). 'Some Aspects of Regional–National Scientific Relations in East Africa'. *Research Policy*, 3(1), 98–123.

**Secretary of State for the Colonies** (1937). *Higher Education in East Africa*. London: HMSO.

**UNESCO** (1991). *Statistical Yearbook: 1991*. Paris: UNESCO.

**Vitta, Paul** (1993). 'Short of Target: Why in Africa Research Rarely Reaches Use'. *Canadian Journal of Development Studies*, 14(2), 245–60.

**World Bank** (1986). *Kenya Agricultural Sector Report No. 4629-KE*. Washington, DC: The World Bank.

———. (1988). *Education in Sub-Saharan Africa: Policies for Adjustment, Revitalization, and Expansion*. Washington, DC: The World Bank.

**Worthington, E.B.** (1957). *A Survey of Research and Scientific Services in East Africa 1947–1956*. Nairobi: East African High Commission.

# 5 The Nigerian Scientific Community: The Colossus with Feet of Clay

**Yvon Chatelin, Jacques Gaillard** and **Anne Sophie Keller**

The scientific future of African, particularly Black African, countries has become a highly debated issue of our time. Similar to the history of the Northern countries, economic and social development has long been acknowledged as going hand-in-hand with scientific development. That was the belief at the 1964 Lagos Conference. It is doubtful whether the relationship is as close in Africa as has been known at certain periods in the countries of the North. Nevertheless, the Nigerian scientific community, which emerged during the 1960s, had experienced an impressive growth during the 1970s (the years of the so-called oil boom). The oil boom years have been followed by a serious recession, developing into the present economic crisis in which the Nigerian scientific community is struggling to sustain its activities.

The emergence of scientific communities is often presented diachronically. This consists of following the history of a sector-based community defined by one or more sets of scientific themes, or a national community. Comparing the histories of several communities after that may prove to be difficult. In studying Nigeria, we adopted a dual approach: diachronic and synchronic. The synchronic approach was applied in the bibliometric study presented in this chapter. It involves characterizing the various countries of a group (in this case Africa) for a given period by applying the same analysis tools to all of them. This holds good for making comparisons.

Before presenting the results of this bibliometric study, this chapter begins with a brief account of the development of scientific institutions in the colonial and independence periods in Nigeria. It is followed by an analysis of the university system which has played a central role in the emergence of the Nigerian scientific community and continues to mark its own trajectory. The impact of the continuing economic crisis on the conditions under which research activities are carried out is also examined. In the concluding section, an attempt is made to characterize the specificities of the Nigerian scientific community. In that context, we think that there are 'types' of scientific communities (see also Chatelin and Arvanitis, 1988, 1991; Gaillard, 1994; Waast, 1995), each of which is defined by both its own particular history and scientific production mode (or 'styles').

## The Development of Science in Nigeria: A Brief History[1]

The development of science in colonial Nigeria illustrates some of the principal features of the British approach. In most cases, research was carried out by British scientists to find solutions to the problems that the British settlers had to face in the African environment. Thus, emphasis was put on research in tropical medicine and agriculture. In medicine, the main objective was to control diseases inhibiting the activities of the colonial settlers. In agriculture, research activities were aimed at improving land use and cultivation, and primarily at developing better cropping systems and higher yielding varieties of cash crops (Eisemon et al., 1985). The first research institutions for agriculture and medicine were founded in the first decades of this century. As far as agricultural research was concerned, a botanical station was established in Lagos in 1883 and a model farm was started at Moor Plantation in 1899 in Ibadan to propagate rubber trees and general agriculture (Evenson and Kislev, 1975). In 1910, the Department of Agriculture established its headquarters at Moor Plantation, where a chemistry laboratory was also constructed in 1926 (Idachaba, 1980).

Like in other British territories, the local colonial government in Nigeria was the main sponsor of research activities in the first part of this century. Initiatives were taken locally and very limited inter-territorial collaboration or coordination took place. Separate departments of agriculture, medicine, etc., were established and staffed with permanent research officers. With forty-nine British expatriates, the number of technical agricultural research staff present in Nigeria in 1938 positioned it in a leading position in Sub-Saharan Africa, after the Union of South Africa (Worthington, 1938). The British staff, although recruited from persons who already had university degrees and research training, often devoted their time to duties that could have been entrusted to auxiliary staff. This made Worthington argue in 1938 that one of the greatest needs of Africa was to train African natives as subordinate staff (ibid.). This lack was felt not only in agriculture, but in every other branch of research activity. Significant metropolitan funding for colonial research was not forthcoming until after the Second World War.

The institutionalization of a regional approach in British West Africa was then greatly influenced by the creation of coordinating and funding mechanisms, and by the organization of conferences at the metropolitan level. Previous colonial experiences called for better inter-colonial coordination of research activities as well as better coordination with metropolitan scientific institutions (Forman, 1940). The first British Commonwealth scientific conference was held in 1938.[2] A colonial research committee was established in 1942 to advise the Secretary of State for the Colonies. This development was instrumental in the establishment of the West African Research Organization (WACRO). This was a regional network of research institutions intended to cover the four British colonies in West Africa: Nigeria, Ghana, Sierra Leone and Gambia. Two of these institutes had their headquarters in Nigeria: the West African Institute for Oil-palm Research (WAIFOR) and the West African Institute for Trypanosomiasis Research (WAITR). WACRO also included: the West African Rice Research Station (WARRS), the West African Maize Research Unit (WAMRU), the West African Cocoa Research Institute (WACRI), the West African Institute for Social and Economic Research (WAISER) and the West African Council for Medical Research (WACMR). Each institute was required to set up its own research stations. In 1957, Nigeria had fifty-seven scientists in seven institutions, while the West African inter-territorial S&T services had seventy scientists in nine institutions (Worthington, 1957). WACRO was dissolved in 1962, two years after Nigeria became independent.

The structure of the institutions provides a simplified but revealing picture of the role ascribed to research. WACRO's organization chart clearly expressed the colonial attitude, with priority given to a number of crops, primarily export crops: rice, maize, palm oil, cocoa. Agricultural scientific development in Nigeria, like all the research in the other countries of Africa, should be recognized as having begun on this basis (see Bonneuil, 1991). The emphasis on commodities in agriculture favoured the adoption of a single-product, problem-oriented approach well suited to large scale producers. This led to the emergence of a dual agricultural economy: a plantation economy[3] serviced by a network of scientific institutions and an African subsistence agricultural economy which received much less scientific attention (Eisemon et al., 1985).[4] Even if food crops were assigned priorities after independence, export crops continue to be predominant in agricultural research. This is in part due to the fact that taxes levied on them provide convertible currency revenue for the governments. Thus, in Nigeria, during the Second National Development Plan (1970–1974), 63 per cent of the agricultural research budget was earmarked for export crops, while food crops received only 33 per cent (Idachaba, 1980).

Until shortly before independence, Nigerians did not participate in the scientific development of their country. Indeed, facilities for the scientific training of Africans did not exist before the establishment of Ibadan University College affiliated to the University of London in 1948 during the closing period of colonialism.[5] This was just the first stage of an important university development. As Davis (1983) points out, scientific research in Nigeria has since become largely a university concern (according to the British tradition), while in Francophone countries it has been linked more to specialized institutions.[6]

## The Considerable Expansion of the Nigerian University System[7]

It was during the latter part of the colonial period that a Nigerian scientific elite began to take shape. The first Nigerian scientists attended Ibadan University College and went abroad for higher levels of specialization. It was then a widely held view in the colonial administration that the university college should limit its programmes to mainly general courses and that the best graduates from the system should be sent to the United Kingdom for postgraduate courses. The demand for higher education, as indicated by the number of students studying abroad, was rising.[8] The first generation of Nigerian scientists have studied abroad. In the 1950s and 1960s, universities in the United Kingdom, especially the universities of London and Edinburgh, were preferred for postgraduate training abroad. In the late 1960s, an increased number of students went to study in the United States[9] and Black American accents became commonly heard on Nigerian university campuses.[10]

According to Adamson (1981), Nigerian researchers soon divided into two rival groups—one supporting the English tradition and the other the American tradition. The distinction between the two groups progressively died out as training diversified. Despite the existence of some nationalist trends, Nigeria does not seem to have experienced any real conflict between national and colonial modes of the magnitude known in India (see Krishna, 1992).

During the early years of independence, there was considerable expansion of the Nigerian university system. From independence to date, twenty-one federal, one military, and nine state universities were established. Today, Nigeria has the largest and most diversified system of higher education in Sub-Saharan Africa. There have been three major periods of university development: the first in the 1960s and early 1970s, when the first generation universities were established; the second in the mid-1970s, when seven more were created; and the third, mainly in the early 1980s, when seven federal universities of technology and nine state universities were established (Table 5.1).

The responsibility for higher education is shared between the local, state and federal governments. Private universities, after a brief experiment in the early 1980s, were prohibited in 1984 due to a mushrooming of institutions of entirely unsatisfactory effectiveness (World Bank, 1988). Student enrollment rose from less than 1,000 in 1960 to close to 150,000 students in 1990.[11] Overall, the rapid expansion of university enrollments has been matched by increases in academic staff until the early 1980s when the third generation universities were established. The relative total dependence on faculty expatriates has fallen continuously since 1965, but the absolute numbers remain high (Table 5.2).

TABLE 5.1
The Nigerian Universities

| *Name* | *Year of Establishment* | *Student Enrollments till 1989–90* |
|---|---|---|
| *First Generation Universities* | | |
| University of Ibadan | 1948 | 12403 |
| University of Nigeria, Nsukka | 1960 | 12403 |
| University of Lagos | 1962 | 10000 |
| O.A.U. University | 1962 | 12479 |
| Ahmadu Bello University | 1962 | 15103 |
| University of Benin | 1970 | 10000 |
| *Second Generation Universities* | | |
| Bayero University | 1975 | less than 3000 |
| University of Calabar | 1975 | less than 3000 |
| University of Port-Harcourt | 1975 | less than 3000 |
| University of Ilorin | 1975 | less than 3000 |
| University of Maiduguri | 1975 | less than 3000 |
| University of Jos | 1975 | less than 3000 |
| University of Sokoto | 1975 | less than 3000 |
| *Third Generation Universities* | | |
| University of Technology, Makurdi | 1980 | less than 3000 |
| University of Technology, Owerri | 1980 | less than 3000 |
| University of Technology, Yola | 1980 | less than 3000 |
| University of Technology, Akure | 1980 | less than 3000 |
| University of Technology, Bauchi | 1980 | less than 3000 |
| University of Technology, Minna | 1980 | less than 3000 |
| National Open University, Abuja | 1980 | less than 3000 |
| The Military University | 1989–1990 | less than 3000 |
| University of Abuja | 1989–1990 | less than 3000 |
| *State Universities* | | |
| Rivers State University of Science | 1980 | less than 3000 |
| Anambra University of Technology | 1981 | less than 3000 |
| Bendel State University, Ekpoma | 1981 | less than 3000 |
| Ondo State University | 1983 | less than 3000 |
| Imo State University | 1983 | less than 3000 |
| Ogun State University | 1983 | less than 3000 |
| Lagos State University | 1983 | less than 3000 |
| Oyo State University | 1989 | less than 3000 |
| Cross River State University | 1989 | less than 3000 |

**Source**: Bako (1990).

The first generation universities tend to have less than 10 per cent of their academic staff composed of expatriates.[12] Conversely, some of the second phase universities remain highly dependent on expatriates. At the University of Sokoto, for example, they comprised 37 per cent of the total academic staff and 74 per cent of the professorial and senior lecturer categories in the mid-1980s. In three other second generation universities

TABLE 5.2
**Teaching Staff in Nigerian Federal Universities, 1965–66 to 1984–85**

| | *1965* | *1968* | *1971* | *1974* | *1977* | *1981* | *1982* | *1983* | *1984* |
|---|---|---|---|---|---|---|---|---|---|
| Total faculty | 1208 | 1288 | 2245 | 3560 | 5190 | 7980 | 8286 | 8829 | 8770 |
| No. of expatriates | 640 | 540 | 606 | 890 | 1142 | 1576 | 1823 | 1767 | 1579 |
| Percentage of expatriates | 53 | 42 | 27 | 25 | 22 | 20 | 22 | 20 | 18 |

**Source**: World Bank (1988).

(Jos, Kano and Maiduguri), more than 30 per cent of the total academic staff and over 50 per cent of the professorial and senior lecturer grades were expatriates during the same period (World Bank, 1988). Today, many expatriate teachers have most likely resigned their posts and left the country, as the foreign currency value of their salaries has been greatly reduced in the late 1980s and early 1990s.[13]

The second and third waves of university expansion were made possible due to the rapid growth of oil revenues during 1973–1980. Although oil prices fell subsequently, the Nigerian government remained committed to the creation of new universities. The very rapid rate of expansion of new universities had a clear negative impact on the financing of the older universities. Shortage of experienced teachers (Nigerian or expatriate) became a serious problem by the early 1980s, when many universities had to rely on teachers on short-term contracts. Overall, shortage of funds has been a problem since the mid-1970s and became particularly acute in the mid-1980s, at the same time when debt servicing increased dramatically. At that time, most universities experienced budget cuts from 50 to 80 per cent. Consequently, many universities could not maintain existing academic facilities, pay lecturers and provide funding for research programmes.

These problems were aggravated by the lack of continuity of the universities' leaderships. According to Kolinsky (1985), many universities had a rapid succession of vice-chancellors for brief periods, which meant that long-term planning was nearly impossible. Furthermore, in spite of the phenomenal growth in enrollments, the needs for higher education are far from being satisfied: out of 233,531 applications, only 33,064 were selected in the country's thirty-one universities in 1990 (Bako, 1990). Yet, while the demands from the states to fill their expanding civil services and the increasing demand for teachers led to virtually full employment of university graduates during the 1970s, there is today widespread unemployment among them.[14]

The IMF/World Bank programmes and policies have contributed to this situation. The World Bank emphasis on 'the poorest-of-the-poor' towards the end of the 1970s has certainly shifted the resources of some donors to some of the least developed countries. Another negative effect of the structural adjustment programme has been the dramatic reduction of the purchasing power of civil servants in general and the consequent massive loss of teaching staff and researchers.[15] A recent investigation conducted at the biggest university in Nigeria, the Ahmadu Bello Zaria, shows that 80 per cent of the senior staff had left in the late 1980s (*Today's Newspaper*, 1990).

Yet, one should not underestimate the impressive achievements of Nigerian universities as centres of learning and research. Over a very short period of time, they have produced a large number of graduates, provided services to people outside the university system and significantly contributed to Nigerian research outputs, as shown later in this chapter. Thus, it is estimated that Nigerian universities represent about 85 per cent of the total research output in Nigeria measured in number of mainstream publications. It is, however, doubtful whether the overall Nigerian university system, given its excessive expansion and consequent cost, is sustainable in the present economic crisis.

## The Federal Research Institutes

Research activities are also carried out in twenty-two federal research institutes which collectively employed about 15,000 scientists and supporting staff in the mid-1980s. As illustrated in Table 5.3, most of the research activity is now oriented towards the use of the natural resources found in Nigeria. There is considerable size variation amongst the institutions, with some employing 100–300 workers, and others employing around 2,000. In general, the largest institutions (like the Cocoa Research Institute and the Forestry Research Institute) tend to be the oldest, while the smallest tend to be the most recent ones (Table 5.3).

A survey of these institutes was carried out by Clark (1980) during the summer of 1977. Information was collected from seventeen institutions. As far as disciplines are concerned, Clark found that the biggest broad category of scientists was that of plant scientists who comprised 62 per cent of total manpower. Within this category, agronomists made up 42 per cent (or 26 per cent of the total), while plant pathologists and soil scientists made up another 40 per cent in roughly equal proportions. Four other broad categories (engineering, animal sciences, social sciences and other sciences) represented around 10 per cent each. Among social scientists, the economists were not integrated directly into the formulation of research projects but were usually involved either in extension work or in specific social studies along with sociologists.

According to the same survey, junior supporting staff, who comprised practically 90 per cent of the total, were overwhelmingly preponderant,

TABLE 5.3
The Federal Research Institutes

| *Institute* | *Speciality* | *Location* |
|---|---|---|
| Cereal Research Institute | Rice, maize and other cereals | Ibadan |
| Institute of Agriculture Research and Training | Lowland rain forests | Ife |
| Institute of Agriculture Research | Sudan and Sahel savannah zone | Zaria |
| Horticulture Research Institute | Fruits and vegetables | Ibadan |
| Root Crops Research Institute | Cassava, yams, other root crops | Umudlike |
| Cocoa Research Institute | Cocoa, coffee, kolanuts | Ibadan |
| Institute for Oil Palm Research | Oil palm and other palms | Benin |
| Rubber Research Institute | Rubber | Benin |
| Agricultural Extension and Research Liaison Services | Information and extension | Zaria |
| Stored Products Research Institute | Storage and preservation | Lagos |
| Forestry Research Institute | Forestry and wildlife | Ibadan |
| Lake Chad Research Institute | Resources of inland lakes | Maiduguri |
| Kainji Lake Research Institute | Resources of man-made lakes | Kainji |
| Institute of Oceanography and Marine Research | Oceanography and marine resources | Lagos |
| Animal Production Research Institute | Livestock production | Zaria |
| Veterinary Research Institute | Livestock diseases | Jos |
| Institute of Trypanosomiasis Research | Trypanosomiasis | Kaduna |
| Leather Research Institute | Leather utilization | Zaria |
| Institute for Medical Research | Medical research | Lagos |
| Federal Institute for Industrial Research | Food science and related fields | Lagos |
| Projects Development Institute | Engineering design and development | Enugu |
| Building and Road Research Institute | Materials and design | Lagos |

**Source**: Schweitzer (1986).

while the proportion of actual research scientists averaged about 5 per cent of the total. In terms of qualifications, around 25 per cent of the research staff possessed PhD degrees, 25 per cent MSc, and 50 per cent BSc degrees. Overall, the skill level of the research scientists in the federal research institutes is lower compared with that of the universities (particularly the oldest universities). Practically all institutes had difficulties in recruiting and retaining suitably qualified staff in the late 1970s, the universities being at that time, and on the whole, more able to offer better career opportunities, better conditions of service and better research facilities.

Many institutes provide a variety of services (some institutes carry out extension and liaison work),[16] but on the whole they are more concerned with transferring technologies already developed. The links with the client sector to develop research programmes at their conception phase do not appear to be very close (Clark, 1980). Much of the time of the research staff is also devoted to education and training, and to routine testing and maintenance services (Schweitzer, 1986).

## The National Science Policy System

Following political independence (proclaimed on 1 October 1960) and the dissolution of WACRO in 1962, the need to create a central coordinating body for research activities received increasing attention in the Nigerian scientific establishment. UNESCO's Lagos Conference on 'The Organization of Research and Training in Africa' held in 1964, reinforced, without any doubt, this need. There were several attempts at organization which then vanished without much effect.[17] The Nigerian Council for Science and Technology (NCST), set up in 1970, lasted longer than the earlier structures and made its mark on the country's scientific community. The creation and organization of the NCST was largely based upon a report prepared by a UNESCO expert, Dr N.R. Martin (Martin, 1970).

NCST was a council and not an autonomous body. With the creation of NCST, Nigerian science policy making and research planning had a three-tier structure, consisting of NCST as the first level of policy making, the research councils as the second level, and both research institutes and university departments as the third level. The research councils represented four major areas of research, already much farther afield than those of WACRO. They were: agriculture (the Agricultural Research Council of Nigeria—ARCN), industry (the Industrial Research Council of Nigeria—IRCN), medicine (the Medical Research Council of Nigeria—MRCN) and natural sciences (the Natural Sciences Research Council of Nigeria—NSRCN). Looking back at the period of NCST control, it seems to have been one of liberalism and relative independence for the various institutions. Basic research prospered.

That liberal period was short lived. Political unrest and the military takeover soon drove the country to a much more interventionist system of scientific activity. A first step towards a new science policy came with the setting up of the National Science and Technology Development Agency (NSTDA) in 1977. This agency (rather than council) had greater managerial powers. Two years later, in 1979, the NSTDA became the Federal Ministry of Science and Technology. It was devoted to increasing the country's S&T activities, and showed a greater desire to manage and control. Bureaucracy became more important. One of the main arguments for consolidating the supervision of research within a central ministry included the need for a strong organizational advocate for research during the time of budget retrenchments and the Ministry's beginnings were indeed marked by a substantial growth in research budgets. Another argument was the opportunities for transferring knowledge among ministries and between federal and state agencies that could be promoted by a central organization (Schweitzer, 1986). However, with successive decreasing budgets, the effective role of the Ministry seems to have been greatly reduced.

The decade of the 1970s was a period of growth for the Nigerian scientific community. Adamson (1981) showed the spectacular growth in the number of university academicians publishing in scientific reviews. The country's six oldest universities were considered in two five-year periods (1970–1974 and 1975–1979). The number of published university academicians or researchers associated with the universities (Institute of Agricultural Research, Institute for Agricultural Research and Training, etc.,) doubled from one period to the next. Davis (1983) indicates a similarly clear growth in scientific production (number of papers published) in Nigeria during the 1970s. That growth was also one of the offshoots of the genuine economic boom from which Nigeria, a petroleum exporting country since 1969, prospered. Scientific research and university education thus benefited from favourable funding and worked to develop technological studies. Petroleum production guided development towards the industrial sector, to the detriment of agriculture.

With the petroleum crisis, which began in 1981, Nigeria toppled into a serious economic recession. The country turned back to agricultural production and manufacturing industries. Scientific activities were affected. According to Eisemon and Davis,[18] the number of Nigerian scientific authors publishing in the most influential international scientific journals monitored by the Institute for Scientific Information (ISI) continued to increase until 1987—when it reached a peak of slightly more than 1,400 a year—to decrease to slightly more than 700 in 1991. Yet, when using a sub-base of the latter, the Research Front Database (which is even more selective),[19] we find that the number of publications published by Nigerian scientists has remained surprisingly constant between 1988 and 1990.[20] This suggests that there was a core of academic scientists in Nigeria who continued to be active and publish in highly reputed journals despite the crisis. Nevertheless, the Nigerian scientific community has to be considered as having spent a full decade in a state of crisis (worsened by the political crisis which we have not even touched on here). Despite these difficulties, the Nigerian scientific community continues to publish and to conserve its supremacy in Sub-Saharan Africa (excluding South Africa), as we shall see in the next part of this chapter.

## Nigerian Research Output in the African Landscape

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.[21] Yet, a number of earlier bibliometric studies have shown that the PASCAL database, established and managed by the Institut National pour l'Information Scientifique et Technique (France), is of particular interest in the context of peripheral countries or communities (Chatelin and Arvanitis, 1988, 1992).[22]

For this present study, we have worked on the PASCAL database for the years 1987, 1988, 1989 and 1990. We have resorted to two levels of analysis. The first involves straightforward database interrogation and the second, the interrogation, retrieval and then processing of bibliographical information. The first level of analysis consists of interrogating the database to obtain the number of references affiliated in each country. We thus obtained the scientific production designated strictly as coming from a country's national laboratories. All publications to do with the country but produced elsewhere were excluded. An initial interrogation gave us the total number of references for each African country.

For the three most important countries, we proceeded with further interrogation so as to obtain the number of references pertaining to four major scientific areas: Physics, Chemistry, Technology; Land, Sea Space; Agricultural Sciences; and Medical Sciences. For Nigeria, we once again interrogated the PASCAL database, asking not only for the references affiliated (by the first author) in the country itself, but also for all the references affiliated in another country, though nonetheless concerning Nigeria. The latter are references where the word Nigeria figures either in the title or among the keywords. The whole body of references were drawn from the PASCAL database and then processed. Unlike the preceding stages, which went on an automatic interrogation of the database, the processing here consisted of examining each bibliographical item, one by one. As an interpreting aid, we used the database classification scheme and keywords introduced by the PASCAL database. The processing was aimed at obtaining a certain number of numerical indicators (on the authors, countries and publications) and establishing a thematic analysis of the scientific production concerning Nigeria.

## Major Features of African Production

The broad lines of the African continent's scientific stage over the past two decades have been described by Rabkin et al. (1979), Davis (1983), and Gaillard and Waast (1988, 1992). We shall compare some of the results of these earlier studies with those obtained by our investigation.

There are over forty countries in the African continent. From the four years of the PASCAL database, we compiled 24,596 bibliographical references affiliated to those countries. Yet, scientific production is very heterogeneously spread. The Republic of South Africa alone accounts for a third of the publications. The top ten countries represent 88 per cent of the continental scientific production. Five of them belong to the English-speaking world (South Africa, Egypt, Nigeria, Kenya and Zimbabwe), with the other five belonging to the Francophone world (Tunisia, Morocco, Algeria, the Ivory Coast and Senegal). For sure, PASCAL is somewhat biased in favour of the latter (Table 5.4). Among these ten countries, we distinguished three groups, separated by differences of both a quantitative (number of publications) and qualitative (themes treated) kind. Nigeria is ranked third in the first group after South Africa and Egypt. Nigeria alone produces almost as many publications as the next four most important countries together.

**TABLE 5.4**
**Number of References from the Ten Most Productive Countries, 1987–90**

| *Country* | *Number of References* |
|---|---|
| *First Group* | |
| South Africa | 8101 |
| Egypt | 4921 |
| Nigeria | 3570 |
| *Second Group* | |
| Tunisia | 1287 |
| Morocco | 969 |
| Kenya | 821 |
| *Third Group* | |
| Ivory Coast | 547 |
| Algeria | 515 |
| Zimbabwe | 432 |
| Senegal | 429 |

When we consider Black Africa (excluding the Republic of South Africa and North Africa), Nigeria's supremacy becomes overwhelming (see Figure 5.1). Nigeria produced 3,570 of the 8,603 references recorded for Black Africa as a whole. It therefore represents more than 41 per cent of Black Africa proper, a percentage which would probably have been somewhat greater had there been no linguistic bias in favour of the Francophone countries.

These results should be put alongside those obtained by Davis (1983) for whom Nigeria and Kenya represented 41 per cent of Black Africa's scientific production in 1970 and 59 per cent in 1979. According to our survey covering the period 1987–1990, these two countries represent 51 per cent of Black Africa as a whole. Therefore, despite the differences introduced by the bibliographical databases consulted by Davis and ourselves, Nigeria's huge supremacy in Sub-Saharan Africa is confirmed. Like the majority of developing countries, Nigeria devotes a larger share of its research activity to the areas of medicine and agricultural sciences (Table 5.5).

**FIGURE 5.1**
**The Five Most Productive Countries in Sub-Saharan Africa**
(excluding South Africa)

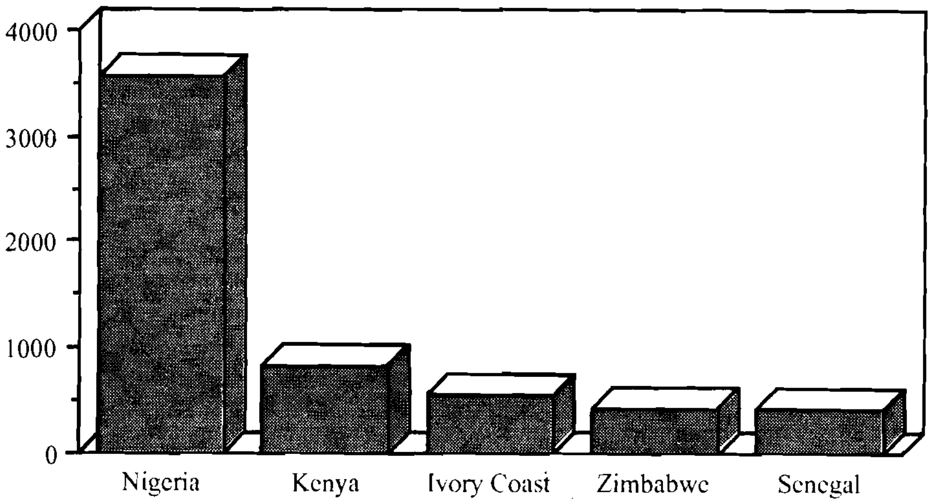



**TABLE 5.5**
**Thematic Distribution of the Top Three Countries—Main Research Areas**

*(Percentage)*

| *Countries* | *Physics, Chemistry, Technology* | *Earth, Ocean and Space* | *Agricultural Sciences* | *Medicine* | *Others* |
|---|---|---|---|---|---|
| South Africa | 18.2 | 17.0 | 9.5 | 29.2 | 26.1 |
| Egypt | 42.2 | 12.8 | 14.5 | 13.8 | 16.7 |
| Nigeria | 12.7 | 13.4 | 26.9 | 32.7 | 14.3 |

Once again, there is a fair correspondence with Davis' study (1983) according to which, for Black Africa as a whole, physical sciences represent 10.1 per cent of papers published, natural sciences 7.1 per cent, agronomy 22.3 per cent, medicine 38.2 per cent and biology 22.4 per cent. In our study, the interrogations carried out on the other countries in the first group (the Republic of South Africa and Egypt) were not controlled with complementary analyses as was the case with Nigeria. The comparison of the three countries has therefore to be considered with some caution.

## The Orientations of Nigerian Research

The four scientific areas used for comparing the whole body of African countries were defined expressly to enable an easy interrogation of the PASCAL database. For a more detailed analysis, we characterized Nigerian scientific production according to seven areas, presented in descending order according to their numbers of publications (see Figure 5.2).

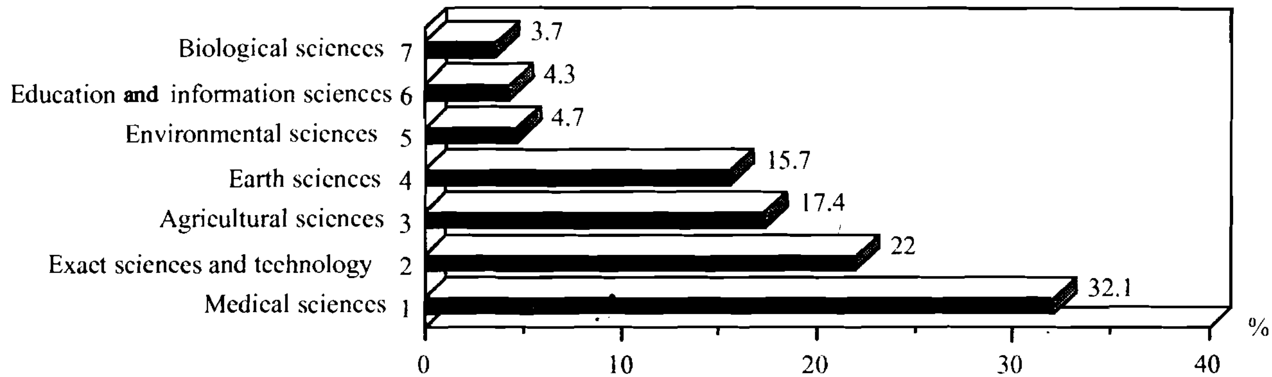
Medical sciences is the most important area (in terms of numbers of publications). It is characterized (as in every country) by the very large share of hospital activity linked clinical studies. Nearly a third of these are to do with paediatrics. We noticed the presence of some studies on contraception (completely lacking in many other countries). The second medical publications group, in order of size, is made up of public health, nutrition and epidemiology. Laboratory work constitutes the third group. This is the one which includes the most basic or advanced research. For a developing country, Nigeria is significantly visible in the areas of immunology, human genetics and, above all, pharmacological research.

The second most important area is exact sciences and technology. It includes a variety of disciplines whose common point is that none depend on either local, ecological or human conditions. Some authors define them as 'cosmopolitan' (Rabkin et al., 1979). The research carried out in this area differs little from one country to the next. Thus, we found a significant presence of mathematicians, statisticians and computer scientists in the Nigerian scientific community. There are also many publications in physics and, above all, chemistry (often focusing on industrial problems). Moreover, Nigeria devotes a great deal of effort to biotechnologies and the food industry. Technological research on energy and civil engineering is also noticeable. The relative importance of this second area sets Nigeria clearly apart from other Black African countries.

Agricultural sciences come in third place. Appearing in this area are the usual themes of agronomical research in tropical countries, that is, crop fertilization, water supply, plant breeding, atmospheric nitrogen fixation, crop protection, zootechnics and veterinary medicine, sylviculture and natural resource conservation. As with all developing countries, these are indispensable fields of research, whose distribution in Nigeria does not seem to mark any particular originality. It is only by going into the details that one might suspect some shortcomings (in virology, maybe, or nematology), a discussion of which is impossible here.

Earth science publications (geophysics, geology, tectonics, geomorphology and soil science), which make up the fourth area, are almost as numerous as those in agronomical disciplines. Earth sciences rarely have such a great relative importance in other African countries. Nigeria's mining interests (petroleum, gas, coal, iron ore, gold, etc.) undoubtedly constitute a motivating factor. However, they are not enough to explain the diversity of the

**FIGURE 5.2**
**Main Scientific Orientations of Nigerian Science**



studies produced and, for instance, such a high number of publications on soil science. Highly specialized or basic research efforts are visible in geochronology, astrochemistry, archaeology and pre-history.

Unfortunately, the fifth and seventh areas (climate and aquatic environments, and biology and ecology) are not developed enough. As in many other developing countries, Nigeria's scientific community seems very much drawn by the basic disciplines and advanced technologies. Despite Nigeria being a seaboard land with a strong network of rivers, relatively few studies are devoted to marine biology, fresh water biology, fisheries and aquaculture. Similarly, study of the country's large-scale natural formations (ecosystems of forests and savannah) seems neglected. The sixth area (information and educational sciences) is not easy to compare. While present in the PASCAL database, it would probably be better-off grouped with the social sciences (not considered here).

## Bibliometric Indicators

A national system of research is formed of elements (institutions, laboratories, researchers) belonging to the country and elements from abroad. We are above all looking at the relationship between the two here, insofar as they can be grasped by the analysis of scientific production. No research system (especially in a developing country) can be made exclusively of national elements. Depending on the case in hand, the importance of the link with (or dependence on) foreign elements can vary both quantitatively and qualitatively. A first question to ask concerns the localization of research, that is, located within the country or outside. The ratio of numbers of publications affiliated in the country to the total number of publications defines the 'indicator of national affiliation' (Table 5.6).

A second question relates more directly to the way research is operated. Bibliometrics provides an approach by defining an 'indicator of associativity' (Table 5.7), which represents the average number of authors per publication.

**TABLE 5.6**
**Indicator of National Affiliation**

*(Percentage)*

| *Country* | *Indicator of Affiliation* |
|---|---|
| Nigeria | 90.8 |
| Ghana | 53.2 |
| Kenya | 55.0 |
| Ivory Coast | 62.4 |
| Senegal | 55.4 |
| Burkina Faso | 38.0 |
| Niger | 38.4 |

TABLE 5.7
Indicator of Associativity

| *Country* | *Indicator of Associativity* |
|---|---|
| Nigeria | 1.9 |
| Ghana | 2.2 |
| Kenya | 2.8 |
| Ivory Coast | 3.2 |
| Senegal | 2.8 |
| Burkina Faso | 2.7 |
| Niger | 2.5 |

A third question to which bibliometrical analysis easily responds is that of 'editorial dependence'. Black Africa is obviously extremely poor in terms of editorial capacities. Some countries nonetheless publish scientific (especially medical) journals of which the PASCAL database regularly takes stock. In the case of Nigeria, as we have defined it, 91 per cent of the publications are printed in a country of the North. Among the developing countries, African or others, we notice that there are three which have published a greater number of studies concerning Nigeria than Nigeria itself. They are, in ascending order, Zimbabwe, India and Kenya.

## A Marked National Character

The Nigerian scientific system has a marked national character. This is what is first shown by the very large amount of studies affiliated to national soil. We are not trying to say that Nigeria is a closed or unwelcoming country but, relatively speaking, there is less research conducted there from abroad than in other African countries. Similarly, international institutions set up on national soil (particularly the International Institute for Tropical Agriculture—IITA) represent too small a share of the national system[23] to enable easy comparison with other international institutions in other countries (Kenya, for example). This goes hand-in-hand with the lowest rate of associativity observed for any of the Black African countries we studied. Comparison with other countries, particularly the heavily assisted ones (Burkina Faso, The Niger), shows that associativity really grows when a country opens up to the outside world. While it may be gaining in scientific autonomy, Nigeria does not appear to be too successful at creating the real internal dynamism (and associativity) which would be desired today. The economic and social situation of Nigeria in the course of the past decades is largely reflected in its scientific production. We have already noted the supremacy of the agronomical and medical disciplines (common to all developing countries). We should also highlight the (relatively) larger numbers of studies on food production technologies, petrol-related geology and petrol industry technology. Being undoubtedly overly focused on more pressing problems, the Nigerian scientific system is little interested in the environment, in the broad sense of the term. Although this, as we see it, is a common flaw in Black African research systems, it is worse here. According to our bibliometric investigations, and as a percentage of the whole body of studies published by each country, Nigeria devotes half as much effort than the Ivory Coast to studying climate, aquatic environments (continental and oceanic waters) and land-based ecosystems.[24]

## A Community Carried by the English-speaking World

Although some sides of scientific Nigeria are relatively closed in on itself, elsewhere it seems to fit easily into the Anglophone world (and into the predominantly English-speaking world of international science). This is probably what explains the apparent lack of national scientific publication. Nigerian researchers publish half of their studies in Great Britain or the United States. The rest scatter far and wide, chiefly going out to reviews in Holland (a country with a highly international publishing capacity), the Federal Republic of Germany, France, Switzerland, Italy, Denmark, Japan, etc. Opening up to the English-speaking world definitely plays a stimulating role. In consulting each and every bibliographical item, one after the other, and noticing how broadly they are dispersed, it really does seem as though the Nigerian researcher has little trouble finding a review which will accept the type of work he/she has conducted.

From the consultation of all the bibliographical items, it also struck us that this manner of publication enhances scientific quality. Here is an example. Medical production always includes a great many clinical reports (case observations). Several African reviews (in Senegal, the Ivory Coast, Kenya) specialize in such reports. Nigerian doctors publish their clinical observations in a Kenyan (English language) review and in the journals of many countries of the North. In the latter, clinical reports appear in a more scientific form and are more readily accompanied by laboratory analysis results.

The attraction exerted by a powerful and diversified English-speaking world of science contributes to providing the Nigerian community with some of its own features. The situation is different with Senegal, for example, where publications essentially appear in the French language, over half of them being published in France.[25] It is also different in Egypt or the Maghrebian countries, where, even in the scientific domain, Arabic plays an exceedingly important role.

## The Impact on Development

To what extent has Nigerian science had an impact on the nation's economic and social development? Given the sizeable research investments and the substantial research outputs produced by the Nigerian scientific community during the past three decades, an answer to such a question seems warranted. During the early 1980s, the Nigerian government started to question the return on investments in scientific research. This forced the executive agencies to document with more care the activities of the research institutions (Schweitzer, 1986). Judging from the studies available, these investments have had mixed or limited impacts on development, even though there are many priority development activities which could benefit from inputs from Nigerian researchers.

Idachaba (1980) studied changes in agriculture by looking at yield increases and sustainability of yield increases per plant and per region over a ten to fifteen year period, and in relation to recommendations made by the research and extension services. The results are varied. For certain plants such as rice, cotton, cocoa and millets, significant success is related to the selection of high yielding varieties. The Institute for Agricultural Research (IAR) (rice and cotton) and the Cocoa Research Institute of Nigeria (CRIN) (cocoa) have the most applicable and practical results. They publish (by far) the most and their work is most often cited. Questionable results have been obtained on sorghum, chick peas and groundnuts. Maize production has definitely dropped. Positive results were obtained when political leaders, research scientists and well-organized producers cooperated closely, and when research institutes had the right scientific ambition and proper management. But, technologies and improved varieties are often not sufficiently adapted to local agro-ecological conditions. Idachaba (1992) suggests a list of five factors accounting for this perennial problem: (*a*) laziness on the part of researchers who are content with research stations' results in the vicinity of their host institution; (*b*) the structure of incentives and rewards which are mainly based on publication outputs; (*c*) poor research management at the institute level; (*d*) the 'recurrent cost trap', especially transport and travelling in which research administrators often find themselves; and (*e*) the low level of mobilization of the intended beneficiaries.

As we have seen earlier, most research is done in universities where success means being published by international journals rather than helping local industry (Ogbimi, 1990). Publications in local journals are not given much recognition even if they may be more instrumental in the local implementation of research results. Researchers have no real incentives to research for practical results, provided they can publish their results in reputed journals and be promoted. Furthermore, the inter-disciplinary team approach to research is not very common[26] and research programmes seldom incorporate the practical concerns of the users.[27] Another weak link in the system for commercializing research results and diffusing technologies in Nigeria is the absence of a strong engineering industry. Yet, the adaptation activities of Nigerian firms with strong international ties are often significant, even if they do not lead to fundamentally new products or processes. In several laboratories of international firms, modest product development activities are taking place. A greater exposure of Nigerian scientists in the federal research institutes and universities to the technical and management approaches of these firms would certainly be beneficial (Schweitzer, 1986).

Overall, research has tended to be supply driven rather than demand driven and the recommendation made by Idachaba (1992) for agricultural research is relevant for many other research areas: 'The challenge is to evolve workable mechanisms for promoting dialogue between researchers and the end-users (farmers) of (agricultural) technologies on the one hand, and between researchers and consumers on the other at the predesign stage rather than at the pre-extension and pre-consumption stage' (ibid.: 5).

The problem of linkages between research and development is one of the major challenges for the Nigerian scientific community. There is an urgent need to transform the research system into a more demand driven system within the existing resources. Even there, the community is facing yet another challenge as most institutions are experiencing successive budget cuts.

## Budgetary Restrictions, Deteriorating Conditions and Survival Mechanisms: Resisting the Crisis?

Following increased budgetary restrictions and the depreciation of the Naira in 1986, the provision of scientific equipments, supplies, books and journals has been severely curtailed. The 'fringe benefits' of academic life, which used to be very attractive after independence, have also clearly deteriorated, if not disappeared completely. The recent statement of a Nigerian scientist (Irele, 1989: 132) from the University of Ibadan is revealing of the difficulties under which research activities are carried out today even in the oldest Nigerian university:

> Because resources have had to be stretched, all the universities in Nigeria now suffer from an acute shortage of facilities. So severe indeed has been the rundown of the infrastructure in some of the older universities that routine teaching is difficult and research often impossible. At the University of Ibadan, for example, which is my alma mater and now the university where I teach, we have been battling for the past ten years with supplying water and electricity. Scientific instruments, not the most

> sophisticated, have broken down and cannot be repaired for lack of spare parts or expertise. The purchase and installation of serviceable equipment is out of the question because of foreign-exchange problems; even the most common chemicals and reagents are in such short supply that science teaching has to do without the standard discipline of experiments. In these conditions, no serious research is possible.

The question is, to what extent and how has the community been able to adapt to such a situation? A survey of 178 scientists in the departments of chemistry, geology and physics of four Nigerian universities carried out in May and June 1986 confirms the testimony of Irele, but at the same time illustrates attempts by the scientists to organize survival mechanisms (Ehikhamenor, 1990). According to the results of this survey, lack of equipment was a serious problem for 78 per cent of the scientists interviewed. More scientists (82 per cent) complained about lack of information as a constraint to research. At the time of the survey, most university libraries had been unable to renew most of their subscriptions for four years. At the University of Ibadan, subscriptions for about 5,700 journals had been cancelled, leaving only about 300 (Eisemon and Davis, 1991). This problem is exacerbated by the fact that most scientists are today unable to subscribe privately to their favourite journals.

Surprisingly, out of the 178 scientists surveyed by Ehikhamenor (1990), only three had given up research activities completely. Fourteen per cent had to change their research orientation to areas where lack of equipment would not be a problem. Nine per cent reported that they got part of their research work done outside Nigeria, which meant travelling overseas to do so, or sometimes involving a colleague overseas in doing an aspect of the research requiring equipment not available locally. Survival strategies are also adopted to contend with the problem of lack of information. As many as 36 per cent of the scientists interviewed reported being able to meet part of their information requirement thanks to the good will of colleagues outside Nigeria who did literature searches for them and supplied them with photocopies of articles. Many of them (35 per cent) used the opportunity of a trip abroad to study the literature. Another 23 per cent depended largely on the few journals they could access; while 12 per cent obtained some information through scientific societies. Even the comments of referees on manuscripts submitted for publication turned out to be an important current awareness service to several scientists. As Ehikhamenor correctly remarks, however, many scientists could not benefit from these survival strategies, and even when they could, research projects had to be suspended for long periods while the scientists waited to receive scientific information or analyses from abroad, or while they waited for the opportunities to travel or send research material overseas.

## Conclusion

Is the Nigerian scientific community, which began to enjoy an enviable international reputation during the 1970s, on the verge of collapse? Many sensible observers, Nigerians or foreigners, who have been to Nigeria recently or who are still actively involved in research activities there are indeed spreading very alarming reports.[28] International funding research programmes active in Nigeria for many years are also reporting decreasing numbers of research grant applications submitted by Nigerian scientists or institutions in a context of steadily decreasing research budgets.[29] Outflow of high skilled Nigerian professionals has also been on the rise, particularly since the later part of the 1980s.[30]

The euphoria of the 'oil boom years' which led to a 'policy' of rapid and uncontrolled university expansion is over. The government, which is no longer able to sustain the ambitious proliferation of academic courses and programmes at all levels and in all universities, is now pressing its universities to raise at least half of their budgets from private sources before the end of the century (Eisemon and Davis, 1991). This is very unlikely.[31] University expansion has also led to increased tensions between teaching, advanced postgraduate training and research.

A more realistic approach would advocate the reorganization of higher education and research systems within the limitations of the resources available. This includes a drastic reduction of courses and programmes which are duplicating each other, the closing of a few universities,[32] and the concentration of research facilities and resources in a number of carefully selected university laboratories and research centres. Collaborative partnerships between the university system, the research institutes and the private sector should also be fostered in postgraduate training and in research. A national debate involving all actors concerned (scientists, research end-users, consumers, economic planners, etc.) could also be launched as a stimulus to reorient the national research agenda in an appropriate direction, taking both the local needs and conditions and the international environment of Nigeria into account.

The Nigerian scientific community is indeed in a crisis. Yet, Nigeria continues to occupy a singular place on the scientific stage of Africa, one whose contrasts, strengths and weaknesses we have attempted to underline—a state of crisis but a scientific production which continues to represent a very sizeable share of the African production; a highly national character but an opening up to the outside world; a lack of balance in the themes studied, with a clear development of basic or technological disciplines (e.g., mathematics, physics, chemistry) due to the predominance of universities in the national research system; and great neglect of research concerning natural environments. The capacity to sustain the crisis by the core of the

Nigerian scientific community, through varied survival mechanisms, is probably one of the main lessons of the recent period. A tradition of excellence cannot be eradicated abruptly once it has taken roots.

## Notes

**Acknowledgement**: The authors would like to thank Charles Davis and Tom Eisemon for their constructive comments on a draft of this chapter.

1. For a more detailed review on the development of scientific institutions and science in British West Africa and in Nigeria, the interested reader can consult Lord Hailey (1938), E.B. Worthington (1938, 1957), Sir Charles Jeffries (1964) and especially Charles Forman (1940).
2. It was preceded by a number of Imperial conferences on matters of importance to colonial economies: sugar production (1931), cotton production (1930, 1934 and 1938), soil problems (1930), forestry (1920, 1923 and 1928) and agriculture (1927) (Eisemon et al., 1985).
3. The area cultivated greatly expanded during the first part of the century. As a way of illustration, the area cultivated under oil-palm increased by 80 per cent between 1928 and 1935 (Worthington, 1957).
4. This is, however, not true for all subsistence crops. Much attention has been paid in Nigeria, for example, to developing strains of cassava resistant to a viral disease already known as cassava mosaic. Cassava was (and still is) an important staple carbohydrate food almost equal in importance to cereals in Nigeria. Satisfactory resistant cultivars have been produced in Ibadan in Nigeria and distributed to farmers with reasonable success. Yet, the interest for this crop can also be explained by its export potential in the form of tapioca or starch flour (Worthington, 1957).
5. Ibadan was the first university college to be established in Nigeria. It was, however, preceded by the establishment in the 1930s of the Higher College and Medical School at Yaba (near Lagos) by the colonial government. Yaba Higher College closed in December 1947, and equipment and books were transferred to Ibadan.
6. See, as a way of illustration, the chapter on Senegal by Jacques Gaillard in this volume.
7. The origin and development of the Nigerian university system has been well documented by a number of authors (Mellanby, 1958; Fafunwa, 1971; Okafor, 1971; Ike, 1976; Kolinsky, 1985, among others). For a more detailed review, we invite the reader to consult them.
8. Between 1949 and 1956, a total of 210 graduates received degrees from the University of London (Kolinsky, 1985). In 1975–1976, about 500 Nigerians were studying for postgraduate degrees in the physical and biological sciences in the United States and in the United Kingdom (Eisemon, 1979).
9. According to Eisemon (1979), 'American universities became better known in Nigeria, largely through the activities of American philanthropic foundations and the United States Agency for International Development which promoted higher education for development'.
10. Many features of the American higher education system have also been adopted such as the credit system, the semester system, and postgraduate studies involving attendance at courses and seminars.
11. Enrollments in all forms of tertiary education are estimated at about 350,000, of which 150,000 are in universities and 130,000 in technical/vocational institutions.
12. Africanization was particularly rapid during the 1960s at the country's six oldest universities where Nigerians predominated in the science faculties by 1973 (Eisemon, 1979).

13. Particularly since September 1986 when the Naira was substantially depreciated.
14. At the end of 1984, the National Manpower Board attempted to investigate the number of graduates who had found employment by the end of their compulsory year with the National Youth Service Corps (NYSC). The results were depressing. Of those interviewed, jobs had been secured by only 6.7 per cent of college educated graduates, 5.7 per cent of polytechnic graduates and 4.4 per cent of university graduates. Of the university graduates, those who had studied law, medicine or education had the highest employment rates: 19, 14 and 13 per cent respectively. Less than 1 per cent of the arts and science graduates had obtained employment. Twelve months later, a sample of 800 of those initially surveyed were recontacted and 540 responded. The results showed that two years after graduating, a third of the graduates remained unemployed (World Bank, 1988).
15. The World Bank has been operating in Nigeria since the early 1950s. Three main phases can be identified: the first phase between 1952–1977 was that of infrastructural development, the second phase of 1978–1989 was of adjustment, and from 1990 it has been of rehabilitation within the framework of a restructuring programme.
16. The Veterinary Research Institute, for example, prepares and distributes animal vaccines; the Forestry Research Institute distributes improved seedlings to farmers, etc.
17. The federal military government created the Nigerian Council for Scientific and Industrial Research in 1966 to formulate a national science policy and coordinate research, but the Council was not formally inaugurated.
18. See Figure 4.1 in the chapter on Kenya by Eisemon and Davis in this volume.
19. Source: SRI International Science and Technology Programme, based on the ISI Research Front Database.
20. 1988 = 383; 1989 = 393; 1990 = 395.
21. The most recent collection of articles on this issue is presented in Arvanitis and Gaillard (1992).
22. PASCAL has a particular limitation, though, since only the affiliation (i.e., the professional address) of the first author of each publication is indicated. This means that in PASCAL, a publication co-authored by three people working in different countries only appears as a single affiliation. In fact, this constraint is less distorting than we feared. The co-authors of a single publication often belong to the same country, or even to the same institution, so one affiliation is then enough. The different authors are not usually cited in alphabetical order and the main author (whose affiliation is indicated) is the first one placed. Whatever the case, we considered that the bibliometry carried out from the PASCAL database simply constituted a survey-based analysis. Results appearing coherent, when they matched up, were taken to be relevant.
23. The scientific production published by the International Institute for Tropical Agriculture represents about 15 per cent of total Nigerian production in agricultural sciences.
24. The research contribution of the Ivory Coast to environmental science has been heavily influenced and marked by the sustained presence of French researchers active in this area, chiefly from ORSTOM.
25. The attractiveness of French scientific journals has, however, somewhat lessened in Senegal to the benefit of other foreign journals (see the chapter on the Senegalese scientific community by Jacques Gaillard).
26. Breeders, for example, work on their own, rather than with plant pathologists, entomologists or social scientists.
27. The breeder is often more concerned with increasing yields than with developing varieties that are adapted to difficult cropping conditions, such as lack of fertilizers (Idachaba, 1980). Sorghum researchers have encountered rejection in IAR, Samaru, because of poor storage of the stalks of the new varieties which were not suitable for fencing and roofing. Maize researchers have also encountered rejection of new varieties by consumers on grounds of colour and palatability (Idachaba, 1992).
28. Personal communications: International Foundation for Science, National Science Foundation and World Bank. See also Irele (1989).

29. As a way of illustration, the number of applications submitted to the International Foundation for Science based in Sweden has become half between 1990 and 1993 (1990: 116; 1991: 83; 1992: 64; 1993: 55).
30. See the figures in Logan (1992), particularly Tables 2 and 3.
31. At present, only 4 per cent of all university revenues come from such sources (Eisemon and Davis, 1991).
32. Under continued budgetary constraints, some courses and postgraduate programmes have de facto already been abolished. A few universities, although they still exist on paper, are unable to continue to provide regular activities (World Bank, personal communication).

## References

**Adamson, I.** (1981). 'The Size of Science in the Old Nigerian Universities—Preliminary Analysis'. *Scientometrics*, 3(4), 317–24.

**Arvanitis, R.** and **J. Gaillard** (eds.) (1992). *Science Indicators for Developing Countries*. Paris: ORSTOM.

**Bako, S.** (1990). 'Education and Adjustment in Africa: The Conditionality and Resistance Against the World Bank Loan for Nigerian Universities'. Paper presented at the Symposium on Academic Freedom Research and the Social Responsibility of the Intellectual in Africa, 26–29 November, Kampala, Uganda.

**Bonneuil, C.** (1991). *Des savants pour l'Empire: la structure des recherches scientifiques coloniales au temps de la mise en valeur des colonies françaises (1917–1945)*. Paris: Editions de l'ORSTOM.

**Chatelin, Y.** and **R. Arvanitis** (1988). *Stratégies scientifiques et développement—sols et agriculture des régions chaudes*. Paris: Editions de l'ORSTROM.

———. (1991). 'Between Centers and Peripheries, the Rise of a New Scientific Community'. *Scientometrics*, 17(5–6), 437–52.

———. (1992). 'Representing Scientific Activity by Structural Indicators: The Case of Côte d'Ivoire 1884–1968'. *Scientometrics*, 23(1), 235–47.

**Clark, N.** (1980). 'Organisational Aspects of Nigeria's Research System'. *Research Policy*, 9, 148–72.

**Davis, C.H.** (1983). 'Institutional sectors of "mainstream science" in sub-Saharan Africa, 1970–1979'. *Scientometrics*, 5(3), 163–75.

**Ehikhamenor, F.A.** (1990). 'Productivity of Physical Scientists in Nigerian Universities in Relation to Communication Variables'. *Scientometrics*, 18(5–6), 437–44.

**Eisemon, T.O.** (1979). 'The Implications of Science in Nigeria and Kenya'. *Minerva*, 17(1), 504–26.

**Eisemon, T.O.** and **C.H. Davis** (1991). 'Can the Quality of the Scientific Training and Research in Africa be Improved?'. *Minerva*, 29(1), 1–26.

**Eisemon, T.O., C.H. Davis** and **E.M. Rathgeber** (1985). 'The Transplantation of Science to Anglophone and Francophone Africa'. *Science and Public Policy*, 12(4), 191–202.

**Evenson, R.E.** and **Yoav Kislev** (1975). *Agricultural Research and Productivity*. New Haven: Yale University Press.

**Fafunwa, A.A.** (1971). *A History of Higher Education in Nigeria*. Lagos: MacMillan & Co.

**Forman, C.** (1940). 'Science for Empire: Britain's Development of the Empire Through Scientific Research'. Unpublished PhD dissertation. Madison: University of Wisconsin.

**Gaillard, J.** (1994). 'The Behavior of Scientists and Scientific Communities', in J-J Salomon, F. Sagasti and C. Sachs-Jeantet (eds.). *The Uncertain Quest: Science, Technology and Development*. Tokyo: United Nations University Press.

**Gaillard, J.** and **R. Waast** (1988). 'La recherche scientifique en Afrique'. *Afrique Contemporaire*, 148(4), 3–29.

**Gaillard, J.** and **R. Waast** (1992). 'The Uphill Emergence of Scientific Communities in Africa'. *Journal of Asian and African Studies*, 27(1–2), 41–67.

**Hailey (Lord)** (1938). *An African Survey*. London: Oxford University Press.

**Idachaba, F.S.** (1980). 'Agricultural Research Policy in Nigeria'. Research Report, no. 17. Washington: IFPRI.

———. (1992). 'Transforming African Agriculture Technologically. Any Hope?' *Business Times*, 25 May, p. 5.

**Ike, V.C.** (1976). *University Development in Africa: The Nigerian Experience*. London: Oxford University Press.

**Irele, A.** (1989). 'Education and Access to Modern Science'. *Daedalus*, 118(1), 125–40.

**Jeffries, C., Sir** (1964). *A Review of Colonial Research: 1940–1960*. London: HMSO.

**Kolinsky, M.** (1985). 'The Growth of Nigerian Universities 1948–1980: The British Share'. *Minerva*, 23(1), 29–61.

**Krishna, V.V.** (1992). 'The Colonial "Model" and the Emergence of National Science in India: 1876–1920', in P. Petitjean, C. Jami and A.M. Moulin (eds.). *Sciences and Empires*. Dodrecht, Netherlands: Kluwer Academic Publishers.

**Logan, I.B.** (1992). 'The Brain Drain of Professional, Technical and Kindred Workers from Developing Countries: Some Lessons from the Africa–US Flow of Professionals (1980–1989)'. *International Migration*, XXX(3–4), 289–311.

**Martin, N.R.** (1970). 'Nigeria: The National Science Policy Machinery, July–September 1966'. Paris: UNESCO.

**Mellanby, K.** (1958). *The Birth of Nigerian Universities*. London: Methuen & Co.

**Ogbimi, F.E.** (1990). 'Preparing for Commercialisation of Scientific Research Results in Nigeria'. *Science and Public Policy*, 17(6), 373–79.

**Okafor, N.** (1971). *The Development of Universities in Nigeria 1968–1969*. London: Longman.

**Rabkin, Y.M., T.O. Eisemon, J.J. Lafitte–Houssat** and **E.M. Rathgeber** (1979). 'Citation Visibility of Africa's Science'. *Social Studies of Science*, 9, 499–506.

**Schweitzer, G.E.** (1986). 'Planning and Conducting Federally Funded Scientific Research in Nigeria'. *Public Administration and Development*, 6, 175–86.

*Today's Newspaper* (1990). 'Cold War at Ahmadu Bello Zaria University'. 21-27 October, p. 3.

**Waast, R.** (1995). *La construction de communautés scientifiques*. Mimeo. Paris: ORSTOM.

**World Bank** (1988). *Nigeria: Costs and Financing of Universities*. Washington, DC: The World Bank.

**Worthington, E.B.** (1938). *Science in Africa*. London: Oxford University Press.

———. (1957). *Science in the Development of Africa*. London: CCTA.

# 6 The Senegalese Scientific Community: Africanization, Dependence and Crisis

Jacques Gaillard

Although of a relatively small size,[1] Senegal with its population of slightly over 7 million inhabitants displays a number of characteristics common to many developing countries. With more than 65 per cent of its work force in the primary sector, it remains a predominantly agricultural nation, despite agriculture's feeble and constantly declining contribution to GNP (approximately 20 per cent).[2] Senegal's trade balance is overwhelmingly negative and foreign debt has become a major constraint for the economy. Since 1980, its economic and financial crisis has caused a decrease in real public expenditure, and an associated decrease in the outlays for education and scientific research.

Senegal's privileged status and Dakar's role as capital of French West Africa have been key determinants in the genesis and development of its research and post-secondary institutions. In order to better understand the origins of the Senegalese scientific community, I will, in the first part of this paper, delineate its historical precedents. The task will then be completed by studying the creation and development of the University of Dakar, followed by the institutionalization of Senegalese research activities. The study will limit itself to public institutions—domestic and foreign—that comprise the large majority of active researchers in Senegal.[3] Finally, I will seek to define the specificities of this community and analyze the problems of its legitimation and operation, before concluding with a few recommendations for the future.

## Historical Precedents

### From Colonial Trading Posts to the Creation of the Afrique Occidentale Française (AOF)

After the discovery of Cape Verde by the Venetian Ca'da Mosto in the mid-fifteenth century, the colonial powers (Holland, France and England) established trading posts all along the coast. However, Senegal was not established until the end of the eighteenth century; Sub-Saharan Africa was until then known merely by its contours. The slave trade reached its peak in the seventeeth century, and by the dawn of the eighteenth century, rubber (made from secretions of the *acacia senegalensis*) cultivated along Senegalese river banks became an important export product that revived European rivalries. The first catholic mission in Senegal was established in 1703, but it was not until the mid-nineteenth century that evangelization was intensified with the creation of the 'Pères du Saint Esprit' congregation (Cornevin and Cornevin, 1964). After the abolition of slavery in 1848 and the decline of the rubber trade, the activities of the Senegalese trading posts diminished. It is also during this time that European industrialization increased the demand for raw materials, altering the structure of colonial politics. Under the direction of General Faidherbe, a strategy of land occupation and cultivation based from the old trading posts began.

In 1895, the conquest was completed and the acquired West African lands were united under what became known as the AOF. Dakar was named its capital in 1902. The 'privileged' situation of Dakar during the French colonial experience is the reason for which Sub-Saharan Africa's first secondary school, the Lycee Faidherbe de Saint Louis, was established in Senegal (1919). Dakar also became the site of the first French-speaking university in Sub-Saharan Africa. The birth of the University of Dakar in 1957 was nonetheless preceded by that of Nigeria's University College of Ibadan in 1950. Before independence, however, Senegalese educational institutions were frequented mostly by French students.

## The First Half of the Twentieth Century: Creation of the First Scientific Organizations and Institutions of Higher Learning

The problems encountered in land use and cultivation pushed the AOF government to gear technical services towards more immediate uses. Hence, the creation of agricultural research stations (the first was created in Bambey in 1921), a meteorological service (reorganized in 1922), and a geological service (created in 1930). Concerning scientific research at the beginning of the twentieth century, the AOF was favoured by the presence of the Committee of Historical and Scientific Studies of the AOF, created on 10 December 1915 by Governor General Clozel. The goal of the Committee was 'to coordinate the research and publication effort about French West Africa, to insure its continuity and to make the results more readily available' (Clozel, 1916: 7–8). Its publications (beginning in 1918 with the 'Annuaires et Mémoires' and later the 'Bulletin d'Etudes Historiques et Scientifiques dé l'AOF') appeared regularly and enhanced the diffusion of many scientific studies about the Federation. The principal research and higher education institutes around which the Senegalese research effort revolves today also found their roots in the early twentieth century.

The National Centre for Agricultural Research (CNRA) in Bambey, 120 kilometres east of Dakar, is Senegal's oldest agricultural research centre. Its present location has been the successive site of the Modern Agricultural Farm (from 1913 to 1921), the Groundnut Experimental Station (from 1921 to 1938), the Experimental Station for Soudanese Sector Agricultural Research (from 1938 to 1950) and the Federal Agricultural Research Centre (from 1950 to 1960). Up until the Second World War, research was almost exclusively centred around groundnut farming and, particularly, plant breeding. Research on food crops (millet, sorghum, cowpea, then cassava and soybeans) was only intensified after 1950. The creation of the Soudanese Sector of Agricultural Research and the establishment of the Centre in Bambey as a federal centre for agricultural research mark the regional focus of Bambey that began in 1950. The transformation of the federal centre into a national centre after independence sparked the decline of this regional focus.

The Institut Pasteur of Dakar, successor to the Bacteriological Laboratory of Saint Louis (1896), was created in 1924 by an agreement between the general government of the AOF and the Institut Pasteur in Paris. Twelve years later, in 1936, the French Institute for Sub-Saharan Africa (IFAN) was created. The idea for the creation of an institute of African studies was conceived in 1931, a time of revived interest in the colonies in France and the year of the Vincennes Colonial Exhibit. The conceptions of the colonial era were clearly exemplified in the debate preceding the creation of the IFAN:

> It is for us a sort of intellectual duty and a requirement of colonial honour to study the countries that we must administer and the people that we must educate and protect. This is, in part, one of the strongest justifications for colonisation, and it cannot be defined in material and economic terms . . . . The establishment of African science is indeed an exigency of our colonial policy (IFAN, 1961: 37).

The arrival of the War retarded IFAN's development projects, as it required the mobilization of almost all of its personnel. The early 1950s were then marked by an increase in personnel at Dakar's IFAN (almost exclusively French at that time) and by the loss of its monopoly with the creation of the Institute of Higher Education. The creation of the Institute on 6 April 1950 laid the foundation for the creation of the University of Dakar.

During the pre-War scientific congresses held in France in 1931 and 1937, expression was given to the need for giving the colonies a research organization whose objective would be to put 'science at the service of the colonies' (Gleizes, 1985: 7). In response, the Office of Colonial Scientific Research (the ORSC, that would later successively become the ORSOM and the ORSTOM) was created on 11 October 1943. Its mission was first to 'devote the largest part of its resources to research on indigenous agricultural production . . . taking agricultural production in the larger sense of the term, encompassing forests and livestock, and the utilisation of agricultural products' (ibid.: 11). Because of the central role of Senegal in the AOF, it was among the first countries, along with Cote d'Ivoire, to benefit from the first overseas centres. The project for a geophysical observatory in M'Bour was conceived in 1946 and finalised in 1949, which was also the year of the creation of ORSTOM's Soil Research Centre in Dakar-Hann. At the outset, ORSTOM was designed to cover the study of soils in the Sahelian, Soudanian and Soudano-Guinean zones. It would later reduce its focus in 1958 and in 1964 with the creation of centres in Niamey and Ouagadougou. In 1960, it became the ORSTOM Centre of Dakar and increased the number of disciplines it covered.

The Dakar School of Medicine, the first unveiling of university education in West Africa, was created in 1918. In 1949, it began offering instruction in physics, chemistry and biology. The Institute of Higher Education was then inaugurated in 1950. These were the principal steps that led to the official foundation of the University of Dakar on 24 February 1957.

## The Rise of the University of Dakar

Located 5 kilometres northwest of the capital, the University of Dakar, which later became the Université Cheikh Anta Diop (UCAD), hosts four major schools (administrative and economic sciences, medicine and pharmacology, science and technology, and arts and human sciences) and a central university library that were founded in 1965. Aside from IFAN, most higher education and/or research institutes were created in the 1960s. These are either institutes with administrative and financial autonomy, like IFAN, or university institutes of departments such as the Centre for Applied Economic Research (CREA) created in 1971 under the auspices of the School of Law and Economics. There is also the Inter-State School of Sciences and Veterinary Medicine (EISMV), a regional school opened in 1968.[4]

In its first few years of existence, instruction at the University of Dakar remained very similar to that of the French universities. In fact, the student population remained mostly French (varying from 61 per cent to 74 per cent) until 1967. But the curriculum was profoundly reformed in 1969, a watershed date in the history of the University.[5] The reform's main goal was to Africanize programmes in order to better adapt course content to national needs and development. Enrollments skyrocketed from 1,012 for the academic year 1959–1960 to about 12,000 in the early 1980s. By 1990, the number of matriculated students reached 17,810. The growth of the student population was especially great in the 1970s, when it rose from 2,500 to 10,000 in the space of ten years (Figure 6.1). The number of graduates, however, did not increase at the same pace.[6] In fact, it remained virtually constant between 1980 and 1990 at around 1,400 per year. The process of Senegalization of students increased in the late 1960s. Indeed, the percentage of French students plummeted from 74 per cent to 27 per cent between 1967 and 1968.

French students today represent less than 1 per cent of the population at the University of Dakar. The percentage of Senegalese students increased from 30 per cent in 1968 to 50 per cent in 1969, to 75 per cent in 1978 and to 87 per cent in the 1990–1991 academic year. The distribution of students along gender lines reveals a disproportionately small female community, particularly within the School of Sciences (12 per cent) and the School of Law and Economics (19 per cent), and to a lesser extent at the School of Liberal Arts (23 per cent). Only the School of Medicine and Pharmacology had achieved parity in 1982–1983 (World Bank, 1991). In the 1990–1991 academic year, females accounted for 23.2 per cent of the student body. Foreign students represent 13 per cent of the total, as the University attracts many students from other French-speaking African countries, particularly Benin, Guinea, Burkina Faso, Mali, Mauritania and Togo.

A quick comparison of student body growth with overall population growth shows that the former has been more rapid than the latter, except during 1980–1985. The percentage of Senegalese students to total population has increased faster than that of the overall number of students to total population, but these figures remain low even in 1990 (approximately ten times less than OECD countries). The number of teachers had also increased markedly during the 1970s, though not as quickly as the student population. The subject of the Africanization of personnel was a recurrent one throughout the 1980s: 'the Africanization of teaching personnel in the best possible academic conditions will be practically completed . . . in July 1989 with the replacement of faculty within the first two cycles at the different Schools' (Niang, 1987). This ambitious objective has almost been attained. In fact, while close to a third (31.9 per cent) of teachers were foreigners in 1984, today expatriates account for less than 10 per cent of the total at the University of Dakar. The extent of Africanization varies according to discipline and level of educational achievement. In 1983–1984, the ratio of Africanization at the University of Dakar reached 80 per cent for teaching assistants, but was significantly lower within the higher ranks: 58 per cent for associate professors and 62 per cent for professors. The School of Sciences is the most reliant on the recruitment of foreign personnel (see Figure 6.2), particularly from France. Women only comprise 10 per cent of the teaching personnel. Their greatest representation is within the School

**FIGURE 6.1**
**Enrollment of Students at the University of Dakar, 1960-1990**

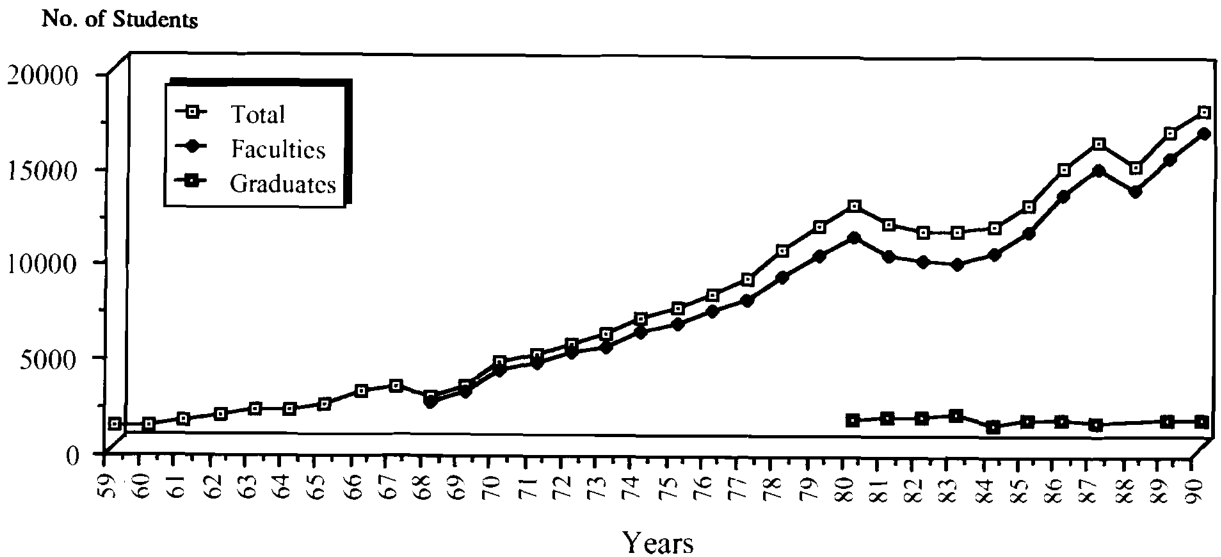
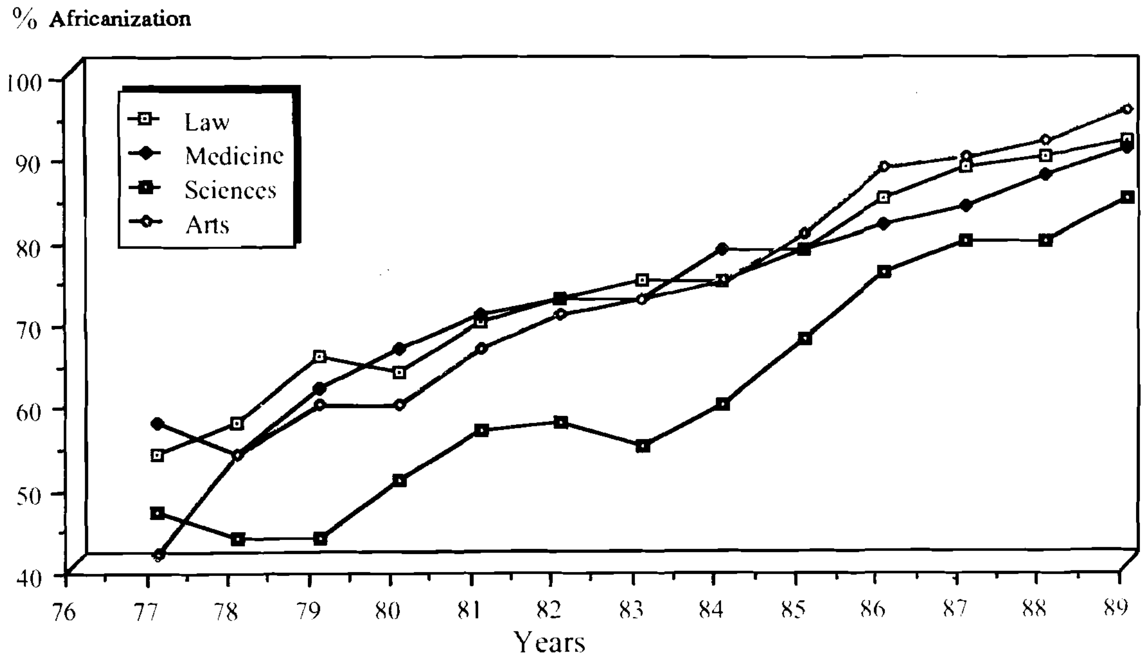


**FIGURE 6.2**
**Africanization of Teaching Staff at the University of Dakar, 1977-1989**



of Medicine and Pharmacology (16 per cent), and their smallest representation within the School of Law and Economics (4 per cent).

The creation of the University in 1957 and of the teaching and research institutions affiliated with the University during the 1960s was accompanied by an institutionalization of research activities in the public sector and by the progressive creation of national bodies responsible for science policy.

## The Institutionalization of Research Activities

Since independence, Senegal has gradually put in place a system for the elaboration of government S&T research policy. Since 1960, an office for the coordination of S&T research was established at the level of the council presidency. In 1966, an executive level Office of Scientific and Technological Affairs was created. It was then supplanted in 1970 by the Direction of Scientific and Technological Affairs, which was directed by the secretariat of state to the prime minister in charge of the plan. In 1973, the Délégation Générale à la Recherche Scientifique et Technique (DGRST) was created and linked to the office of the prime minister. In 1979, the DGRST was transformed into the Secretariat of State for Scientific and Technological Research (SERST), which became the Ministry of Scientific and Technological Research (MRST) in 1983.

After the ministerial reconfiguration in 1986, MRST was dissolved and part of its duties conferred to the new Direction of Scientific and Technological Affairs (DAST) created within the Ministry of the Plan and of Cooperation. DAST was later moved to the Ministry of National Education and then to the Ministry of State Modernization and Technology. With the nomination of a delegate in-charge of S&T research in 1992, the situation was reverted to what it was in 1970. Speaking of the circumstances created in the immediate aftermath of the ministerial reshuffling of 1986, the former minister of research stated:

> The changes put in place represent the complete dismantling of the conceptual model of national scientific policy, and its replacement with a new model. This new model detaches the administration of research structures from the directing body of science policy, and relinks them at the level of the departments that depend on them (cited in Ndiaye, 1988: 303).

This is how the Senegalese Institute of Agricultural Research (ISRA) became incorporated into the Ministry of Rural Development. As feared by the former minister of research, the DAST was unable to effectively assume its coordinating duties:[7]

> Our experience shows us that effective coordination can be achieved only if DAST were given the sufficient authority and financial control of research activities, regardless of the structure within which those activities take place. The budgetary envelope for research should be globalised, and DAST placed in charge of its evaluation and distribution, and of the technical and financial responsibilities associated with individual research projects (cited in Ndiaye, 1988: 304).[8]

Nonetheless, DAST is in-charge of assembling the sectoral consultative commissions.

Agricultural research activities were directed by French institutes up until 1974, the year of the signing of a new agreement for scientific and technological cooperation with France. From 1975, in accordance with the agreement, all agricultural research (agriculture, livestock, forests, fishing) formerly directed by French institutes was to be transferred to ISRA, except for the autonomous ORSTOM. The creation of ISRA was accompanied by a redeployment of research personnel in regional stations and by the accelerated Senegalization of agricultural research. In the agro-industrial sector, the creation of ISRA was preceded by that of the Institute of Food Technology (ITA), founded in February 1963. ITA, which has benefited from FAO assistance, displays a particularly high level of Africanization of research personnel (93 per cent), although their numbers are small (29 researchers in 1985).

Focusing now on the contents of the VIIth Plan of Economic and Social Development (1985–1989), it is striking that research does not figure in any part of the Plan's twenty-one Priority Action Programmes (PAP). The 'Etudes et Recherches du Plan' claims that the national programme for economic and social development will be supported by R&D, but it is clear that the principal thrust of the Plan remains economic and financial adjustment. Research is only included as a response to the immediate needs of the productive sector. It is significant that the term 'research' is only mentioned three times in the twenty-one PAP documents, in relation to plant breeding and soil conservation, and to lignite and non-conventional construction materials (VIIème Plan, 1985–1989).

The directing body of science policy and Senegalese scientific research in general have been altered by the deep economic crisis and its associated budgetary austerity. The changes have manifested themselves in the form of an erosion of power for the directing body of research, a decrease in the governmental resources devoted to research (and a heightened dependence on the providers of the funds, notably the World Bank) and a re-evaluation of projects destined to improve the national scientific community.

## The Scientific Community

Although there is little data available on the Senegalese scientific community at the time of independence, it can be affirmed that there were few people with university training, with the possible exception of the field of medicine. A few Senegalese were fortunate enough to pursue their studies in France before their country's independence. Among these, the two most illustrious are undoubtedly President Leopold Sedar Senghor and Cheikh Anta Diop, the professor whose death in February 1986 profoundly affected the Senegalese scientific community. When Senegal achieved independence, he was one of the few, if not the only, Senegalese researcher at IFAN. Only after 1960 were the first Senegalese grant recipients and fellows sent to study in France.

The first inquiry into Senegal's science and technology potential (STP) elucidating the characteristics of formation and composition of the Senegalese scientific community was conducted in 1972–1973. A second survey was produced by DGRST in 1975. In 1981, UNESCO also made available a study of the STP for the West African Economic Community (CEAO), of which Senegal is a member (UNESCO/PNUD, 1985). Although it is difficult to establish comparisons between surveys because of their different methodologies and definitions,[9] we will attempt to rely on the aforementioned surveys, complementing them with direct inter-study comparisons to delineate the main characteristics of the Senegalese scientific community.[10]

### A Community on its Way to Senegalization

The 1975 report and analysis of STP presents in its chapter on human resources a portrait of the typical researcher in Senegal fifteen years after independence: he is 39.1 years old, has a 91 per cent chance of being male, a 50 per cent chance of being French, while only a 30 per cent chance of being Senegalese (Gillet, 1976). What this preliminary data reveals above all else is the heavy dependence of the Senegalese scientific community vis-à-vis French researchers. The proportion of French researchers in the 1973 survey shows an even greater dependence. Senegalese researchers then accounted for only 20 per cent of the 416 per researcher scientific community (CNPRS, 1973). In addition, Senegalese researchers tended to concentrate on the scientific disciplines of medicine (39 per cent versus the average 22 per cent) and social sciences (18 per cent versus 13 per cent), while they were relatively less numerous than expatriates in agronomy and biology. The large majority of expatriates are French. Non-French expatriates generally come from the neighbouring French-speaking African countries and are concentrated within the University. In 1973, there were a few

Belgian and Dutch researchers; today they are joined by several Americans and Asians.

The Senegalization of the scientific community accelerated during the 1970s. The latest survey was carried out in 1981 and looks at 828 researchers. It paints the opposite picture of the 1973 survey: 75 per cent are Senegalese, 20 per cent are French and 5 per cent are non-French expatriates (of which 4 per cent are non-Senegalese Africans). Among the remaining 1 per cent expatriates, there are nine Belgians, three Italians, two Britons, two Americans and one Indian. From the data available in 1990 on teacher/researchers at the University and the main research institutes (ISRA, ITA and ORSTOM), it appears that approximately 75 per cent are Senegalese (see Table 6.1).

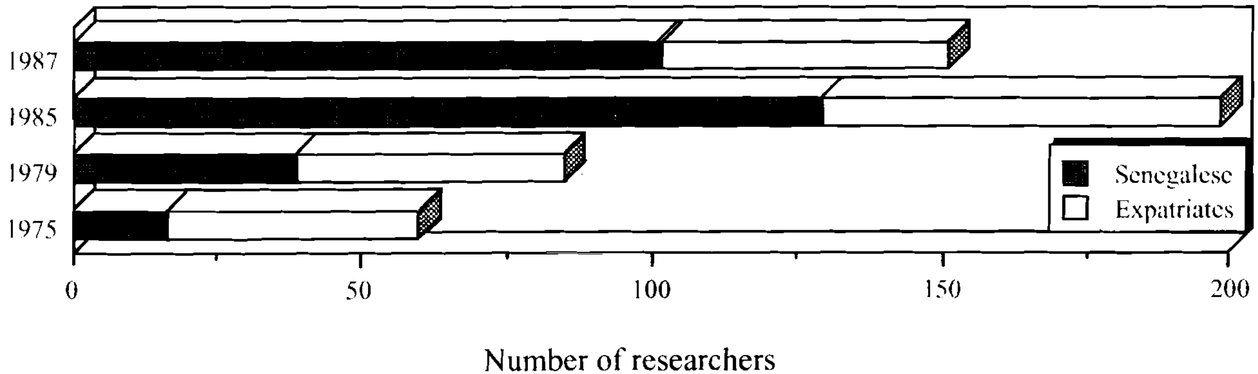
**TABLE 6.1**
**Distribution of Senegalese and Expatriate Scientists in the Main Public Institutions**

| | *Expatriates* | | *Senegalese* | | *Total* |
|---|---|---|---|---|---|
| *Institutes* | *Number* | *Per cent* | *Number* | *Per cent* | *Number* |
| *Universities** | | | | | |
| UCAD | 65 | 11 | 536 | 89 | 601 |
| Institutes affiliated to UCAD | 53 | 22 | 192 | 78 | 245 |
| ISRA* | 60 | 35 | 110 | 65 | 170 |
| ITA** | 2 | 7 | 27 | 93 | 29 |
| ORSTOM* | 108 | 88 | 15 | 12 | 123 |
| Total | 288 | 25 | 880 | 75 | 1168 |

* in 1990, ** in 1985

With the exception of ITA, it is within the four UCAD schools that the percentage of Senegalese is highest—nearly 90 per cent. ORSTOM, being the only remaining French public institution with its own research centre in Senegal, is an exception to the dominant trend. This explains the particularly high proportion of French expatriates among its scientific personnel. Nevertheless, efforts have been made since 1983 to integrate young Senegalese researchers into ORSTOM, especially in its microbiology laboratory and in projects defined in conjunction with Senegalese research institutions. A training agreement was also signed by ORSTOM and Senegal in 1990[11] and talks are currently under way for the transferring of the Bel Air Centre in Dakar to Senegalese authority. The percentage of Senegalese in the national scientific community has rapidly increased since the early 1970s. Senegalese researchers and technicians now make up the majority of ISRA (see Figure 6.3). In 1974, the year of ISRA's creation, there were only eight nationals among approximately fifty scientists involved in agricultural research.[12]

**FIGURE 6.3**
**Number of Researchers at ISRA, 1975-1987**



Estimating that the institutions listed in Table 6.2 represent approximately 80 per cent of the Senegalese scientific community—a realistic hypothesis—the number of teachers, researchers and engineers associated with higher education and R&D can be placed at about 1,500. These scientists devote a varying proportion of their time to research. It ranges from almost 100 per cent for some researchers in research institutes to virtually 0 per cent for a large majority of University professors. The portrait of the average researcher working in Senegal differs greatly in function, depending on whether he works within or outside the University. This difference is described in the following paragraphs.

**TABLE 6.2**
**Number of Scientists in the Main Institutional Sectors in 1990**

| *Institutional Sectors* | *No. of People* | *No. of Researchers (Full-time Equivalent)* |
|---|---|---|
| University | 855 | 128 |
| Public Research Centres | 435 | 313 |
| Total | 1290 | 441 |

## The Under-utilized University Research Potential

Because the precise data for the private sector is unavailable, I will limit my analysis to public sector organizations.[13] The results of the 1985 survey show that the average age of researchers is 34 (5 years younger than in 1975).[14] The experience of researchers, in number of years, has also declined. It averaged about ten years in 1975, but stood at only about six years at the end of the 1980s. University personnel also tend to be younger than their colleagues in research institutions. The main distinction between the university and non-university researcher was the amount of time he devoted to research. Non-university researchers claimed to spend 72 per cent of their time on research, while university researchers only declared it to occupy 47 per cent of their time, and even that seems to be an excessively high percentage for the university sector. What is more, according to a DAST report, approximately 15 per cent of the teachers are involved in university research activities,[15] Using these percentages, we can estimate the equivalent full-time (EFT) research potential in the two main institutional sectors (see Table 6.2).

While representing almost two-thirds of the Senegalese scientific community, researchers at the University of Dakar represent less than one-third of the EFT researchers. The University potential is, therefore, significant, but largely under-utilized in research activities. In addition, teacher/reseachers at the University of Dakar are well trained; more than half (55 per cent) of them had a tertiary degree in 1981 (AUPELF, 1984). Among these, 16 per cent also had a doctorate degree. The high level of preparation of University teacher/researchers is confirmed by other studies undertaken in the area.[16] Comparatively, ISRA researchers are half as likely to have a tertiary degree or equivalent—a measure of true research specialization.[17]

On the other hand, the means devoted to University research are few. According to a 1981 survey, research spending accounted for no more than 3.6 per cent of intramural University spending (UNESCO/PNUD, 1985). Another study for the 1990–1991 academic year estimates (probably excessively) the figure to be 11.6 per cent, of which more than half (56.6 per cent) corresponds to salary expenses (DAST, 1991). The real amount probably lies somewhere in between the two estimates, and it is wholly inadequate. The different analyses of the Senegalese scientific potential highlight the lack of technicians employed in research activities, particularly at the University. A better use of University R&D potential, whose importance has been shown, appears to be necessary.

## Training: A Strong Foreign Dependence

In the different schools at the University of Dakar, there is for most disciplines tertiary instruction leading to the obtention of a Diplome d'Etudes Approfondies (DEA)[18] and to the defence of a PhD thesis. Nevertheless, the structures, equipment and the number of supporting staff are insufficient to accommodate the research training of young Senegalese scientists. The training of researchers, therefore, depends largely on the obtention of fellowships for study abroad. In 1981, there were no fewer than 3,380 Senegalese students pursuing tertiary training abroad (UNESCO, 1985), four-fifths of which were in France.[19]

The relative dependence on foreign training for tertiary studies that eventually leads to a career in research is a function of the researcher's specialization. Training in medical science is conducted for the most part in Senegal. In other areas, such as in agricultural research, foreign dependence is very high. Of the 131 high level Senegalese researchers and technicians at ISRA in 1985, only twelve (9 per cent) had conducted their higher education in Senegal. The fact that there was no institution for higher education in agriculture before 1979 is largely responsible for this. A priori, it seems paradoxical and absurd that a nation that devotes more than half of its research expenditure to the field of agriculture and which possesses formidable research potential in that sector would not sooner put its human capital and experience to use in the training of its own researchers.

The breakdown of ISRA researchers by country in which they conducted their training shows the multiplicity of sites chosen for training, which include USA (where twenty-eight ISRA researchers have been trained), countries in Western Europe (besides France) and Asia. With 43 per cent of ISRA's researchers trained within its borders, France remains the most frequent choice for training of Senegalese researchers in almost all fields. USA has only participated in this training for a few years, and seems to specialize in a limited number of disciplines—economics and rural sociology in particular. It is expected that USA's involvement in such activities will increase in coming years. USAID has proposed to train forty PhDs and twenty-five MScs for ISRA in the 1989–1996 period.[20] But these estimates appear overstated, given the grants offered by other countries and the limited recruiting capacity of ISRA.

In effect Senegal, like the majority of the LDCs, must confront the new phenomenon of intellectual unemployment (Jiminiga, 1986). The figures have attained worrisome levels, and virtually all fields are affected. The main providers of employment, the state and private enterprise, have stopped offering jobs. An association of unemployed scholars, organized by speciality, has been in existence since 1981. It is estimated today that 2,000 to 3,000 of the unemployed hold Master's degrees and that the situation will worsen in the coming years (World Bank, 1991).

## A Community in Search of Status

Senegalese researchers working in national research institutes are victims of a lack of social status and career stability that puts into question the future of the research profession. Yero Sylla (1986), former president of the Association of Senegalese Researchers, distinguishes among three categories of researchers: researchers that have become administrators of different bodies (academic, engineering, etc.), contractual researchers like those at the ITA and at the University, and researchers at institutes such as ISRA.

The institutional rules at ISRA do not allow reseachers to follow a 'normal' career, for those rules do not acknowledge the specificities of research and seem to privilege function over merit. The decree on which ISRA is founded gives priority to its administrative function rather that its research function. A researcher at ISRA will only advance in his career if he achieves a post of administrative responsibility (that is, director of a centre or department chief).[21] Until very recently,[22] university researchers such as those at IFAN were recruited by special contract and promoted according to a rectorial decree signed in 1975 that does not include advancement by category. Researcher-administrators may be considered at a disadvantage for such posts since there is no doctorate level salary grade. Holders of a doctorate, of a DEA, of a Master's or of a Bachelor's degree are all in the same category and are promoted according to seniority. These researchers experience the drawbacks of the public sector (low salary) without benefiting from the advantages (job security), because they are employed by the public sector but are not accorded the rank of civil servants.

Because of the heterogeneity of researcher circumstances and careers, there have been several attempts at giving all researchers common status. The SERST and MRST have reformed their classification of researchers and technicians, modelling it after the method used for University teaching personnel, thereby taking researcher status more fully into account. The Association of Senegalese Researchers and the Association of University Technicians worked towards this goal, which was on the verge of coming to fruition when MRST was dismantled. The absence of status marginalizes researchers and devalues the attractiveness of the profession, causing the exodus of the best individuals towards sectors of activity that are more socially and financially attractive such as development, administration or foreign projects.[23]

## Scientific Output and its Impact on Development

MAINSTREAM SCIENTIFIC PRODUCTION: The measurement and evaluation of African scientific output is problematic.[24] A large portion of the work is either published in local journals not indexed in bibliographic databases or in documents that are never published. The most conventional measure of scientific output consists of counting the number of publications indexed in international databases. Among these, the most frequently used is the Science Citation Index (CSI) of the Institute for Scientific Information (ISI).[25] The number of yearly Senegalese publications registered by the ISI from 1970 to 1990 has consistently placed Senegal in either the sixth or seventh place in Africa, with slightly over 4 per cent of the African total. This is on par with a country like Cote d'Ivoire, but far behind the African 'giant', Nigeria, that produces close to half the African mainstream publications (Zymelman, 1990; Gaillard and Waast, 1992).[26] Researcher productivity is weak, however (approximately one publication for every full-time researcher per year in the early 1970s), and has sagged further during the 1980s.

Drawing from the references indexed in the CSI during the 1970s, Davis (1983) also shows that the largest portion of publications are produced by teacher/researchers at the University of Dakar (40 per cent) and by researchers of French bilateral organizations (35 per cent). Researchers from the national research institutes are only responsible for about a fifth (19 per cent) of the mainstream scientific production (ibid.). Because ISI is an English database, it is interesting to compare the results obtained with PASCAL, a French database.[27] What is most evident is that the CSI appears to have a bias against French-speaking countries—the PASCAL database contains twice as many references than does CSI.[28] The data available in PASCAL confirms the preponderance of the university sector. Up until 1985, it was responsible for more than half the scientific output indexed by the Francophone database. The university sector, however, has experienced a rapid drop of output in the years following 1985 (see Figure 6.4).

ORSTOM has been the next most prolific entity with, depending on the years, one-fifth to one-fourth of the references.[29] The ISRA, despite its high potential, is less visible and its scientific production more irregular. This can be explained in part by its focus on more applied research and its corresponding lack of an international or mainstream publication strategy. It will be seen later that much of ISRA's work is published as 'grey literature'.

The distribution by major research fields shows that the most productive are those of health[30] and environment.[31] Technological research is progressing, but very slowly. Another important characteristic of Senegalese scientific production is its dependence on foreign authors; more than two-thirds of the authors are foreigners, principally French (Figure 6.5).[32] The contribution by Senegalese authors has increased in the 1980s, chiefly because of the increase in the number of Senegalese authors per publication.[33]

Although the number of EFT researchers has nearly doubled from 1975 to 1985, it should be noted that the productivity per researcher has declined. The number of publications is not the only measure of scientific productivity and many factors can distort the validity of this indicator. The avenues for publication, especially locally, are limited and increases in the number of researchers are not necessarily associated with an increase in the number of national journals. In addition, the regularity of publication of local journals and bulletins is often a function of the means at their disposal, which are becoming increasingly uncertain.[34]

The few national journals that are diffused regularly are often backlogged and researchers increasingly look towards foreign journals for publication. The proportion of papers published in Senegal has fallen between 1975 and 1990, going from approximately 30 per cent to less than 10 per cent, while the percentage of Senegalese researchers within the national scientific community has increased markedly. More than three-quarters of Senegalese scientific production is published abroad, most often in France.[35] However, the attractiveness of French scientific journals has lessened with respect to other foreign journals (principally British, American and Dutch). This evolution has been associated with an increase in the number of publications written in English. More than one-third of Senegalese scientific production

**FIGURE 6.4**
**Number of Documents by Institutional Sector**

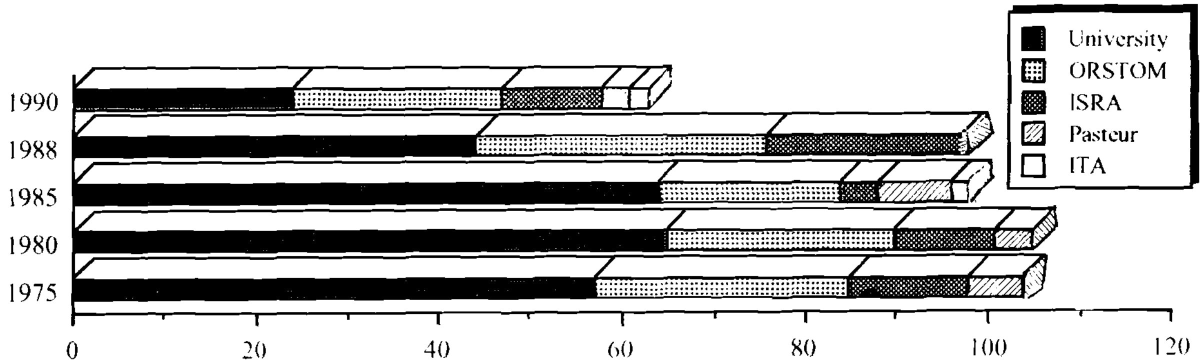
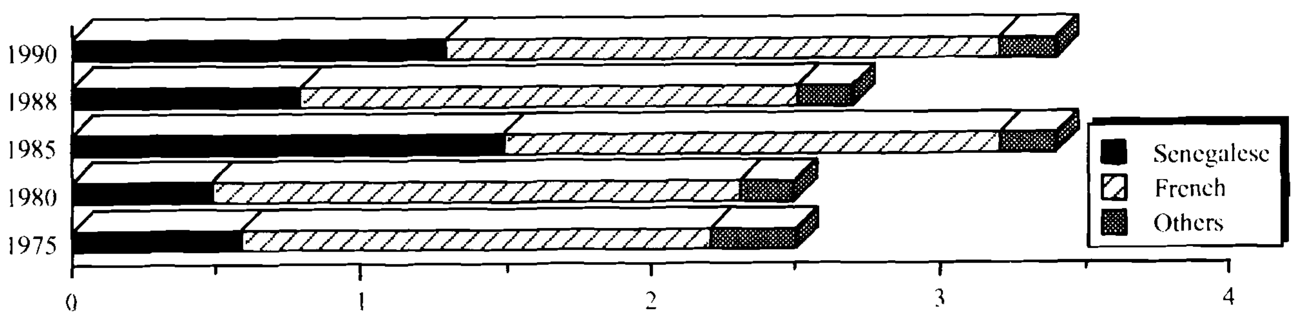



**FIGURE 6.5**
**Number of Authors by Document**



is published in English; in 1975 this proportion was only slightly over 10 per cent.

Although the bibliometric indicators found in international databases present certain advantages, they do not paint a complete picture of overall scientific production. This is especially true for scientific work that bears mainly on problems of local interest. For this reason, it is interesting to examine the scientific output of researchers at a single Senegalese institute. I have chosen ISRA (whose output, as has been shown previously, is scarcely visible in the PASCAL database), which has recently published an analytic bulletin of in-house research work in 1986.[36]

ISRA'S TOTAL SCIENTIFIC OUTPUT: The preface of ISRA's bulletin (ISRA, 1988: 1) begins by posing the question that is the crux of the dilemma: 'How can we know that during ISRA's 13 years of existence more than 2,500 writings, reports, articles, technical fiches, published or "grey literature", were produced by its researchers'. Certainly, this cannot be done by consulting international databases! The establishment of the ISRA database and the publication of its bulletin fill a large void by proposing an indicator based on scientific communication.

The 1986 bulletin shows an output of 207 references distributed among 135 authors. Given that ISRA employed 144 researchers in 1985 (150 in 1986), it can be inferred that, with a few exceptions, almost all researchers recorded their work in one form or another. A large majority of the researchers authored one (57 per cent) or two (18 per cent) papers. The average number of authors per paper (1.5) is lower than that of the overall Senegalese mainstream scientific production (3.7 in 1985). The proportion of Senegalese authors or co-authors represents a majority (52 per cent), although it is slightly lower than that of Senegalese researchers at ISRA in 1985 (62 per cent). The low figure for the average number of authors per paper is explained in part by the nature of the recorded works, which are most frequently internal reports (often individual) and activity reports.

More than two-thirds (69 per cent) of the papers are internal to ISRA, including activity, convention and mission reports. Very few are published in speciality journals: of twenty-one published papers, nineteen were part of two collections prepared for the International Commission for Tuna Conservation. It should also be noted that a large number of works referred to colloquium transcripts (national and international) and internal seminars held at the institution. Contrary to what is found in surveying international databases, most researchers at ISRA do indeed record their work, but the documentation of their research results rarely appears published in speciality journals. Only rarely do these researchers publish in English (just seven out of 207 references).

THE IMPACT ON DEVELOPMENT: Promising results have been achieved in health (leprosy and AIDS). Occasionally, articles in the local (or foreign) press display results obtained in some laboratory or the other. This was the case for the research (at ORSTOM, ISRA and the University) on the *sesbania rostrata*, a tropical vegetable that displays a remarkable capacity for nitrogen-fixation and that may be used as 'green' fertilizer, especially in rice cultivation. But can the impact of such research on development and its effects on daily life be adequately measured?

Unfortunately, there is an insufficient amount of information available to satisfactorily respond to such a question. The few known pertinent studies in agriculture suggest that there has been a fall in agricultural productivity (Braibant, 1986) and a decrease in rural population's income since the early 1960s (except in eastern Senegal and Cape Verde) (Sene, 1985). But even proven correlations between research and socio-economic progress or regression do not provide information about the process of diffusion or about the role of research. It is therefore necessary to conduct keener sectoral analyses and in-depth case studies within each of the sectors.

Sene (1985) has attempted to do this for agricultural research. Other sectoral studies would be needed to make more general judgements. However, he finds among his primary conclusions that:

- Productivity of Senegalese research has decreased markedly in the last fifteen years, in terms of both the technical themes undertaken and the scientific publication of researchers.
- The area in which the fruits of research have been most widely diffused has been that of the groundnut basin, which comprises the highest concentration of Senegalese researchers.
- For lack of follow-up studies, much of the research becomes quickly outdated. This is the case of rice cultivation in the delta and valley of the Senegal river. Of the 16,000 hectares of soil devoted to the cultivation of rice in 1984, only 64 hectares were planted with varieties resulting from research. Likewise, in Casamance, grain varieties produced by research are no longer in use.
- Research results are often not used in practice because of the lack of credit and the high cost of inputs relative to outputs. The quantities of fertilizer applied are often well below recommended levels and they often hover around the threshold of utility.

Faye and Bingen's analysis of relations between ISRA and the potential users of its research results also shows 'the absence of a clear perception of differences in research clients and their specific needs' (1989: 40–41). It was only in 1987 that the Unit for Valuation of Research Results (UNIVAL) was created at the level of the direction generale, but it has not yet been given the means or personnel that would allow it to be functional.

The usefulness of scientific results is difficult to ascertain. Their effects can be difficult to isolate and can appear with significant time-lags. The effect of Senegalese agricultural science has to this day remained limited. In addition, the end of the agricultural programme[37] in 1979 has led to the suppression, or at least the reduction, of subsidies to farmers in accordance with the World Bank-inspired policy of 'getting prices right'. An almost complete stoppage of equipment provision to peasants and a sharp fall in the consumption of fertilizers have followed. This policy has caused 'an end to the diffusion of technologies and a fall in Senegalese agricultural production' (Sene, 1987: 10). In such an environment, the goals set forth by the New Agricultural Policy in 1984 may never be achieved.[38]

## Research Funding: Foreign Dependence and Declining National Research Effort

The funding structure of Senegalese research activities has been relatively stable over time. External resources account for about two-thirds of the amount (see Table 6.3). After a period of relative growth in the national research effort in 1972–1975, where Senegalese contribution to the total resources rose from one-fourth to one-third, the government's portion of funding has remained virtually unchanged. During that same period, there was a diversification of external financial resources and a relative decline in France's contribution from 59 per cent in 1972 to 35.5 per cent in 1986. This diminution can be traced to the recent involvement of the United States (principally USAID) and the World Bank. These two accounted for almost one-quarter of the funding (23.8 per cent) devoted to research in Senegal, after being practically absent in 1975.[39]

**TABLE 6.3**
**Sources of Research Funding in Senegal**

*(Percentage)*

| *Sources of Funding* | *1972* | *1975* | *1986* |
|---|---|---|---|
| Senegal | 25 | 33 | 32 |
| Foreign Sources | 75 | 67 | 68 |
| France | 59 | 57 | 35.5 |
| World Bank* | – | 0.5 | 16 |
| United States* | – | 0.5 | 7.8 |
| United Nations | 9.5 | 3.4 | 1.1 |

**Source:** Analyse du potential scientifique et technique for 1973 and 1975; for 1986 cf. Fondeville (1986: Tables 30 and 33 in Annex).

* No data available for 1972.

In 1986, the largest part of external contributions came from foreign nations (particularly France and the United States), then (in decreasing order of importance) the multilateral organizations (especially the World Bank), a group of foreign public organizations (4.3 per cent) and regional organizations, whose contribution has been relatively marginal (0.8 per cent) (Fondeville, 1986). The 1986 study, far from being the most exhaustive, reveals no fewer than thirty-nine different sources of funding (ibid.). It should also be noted that most of the foreign aid is spent on the disbursement of salaries for predominantly French expatriate researchers.

The ratio of national to external resources is in danger of falling in the future because of the Senegalese government's persistent economic and budgetary difficulties, and of the conditional aid from the World Bank requiring cuts in public expenditure. The falling government outlays, beginning in 1985, have led to recurrent deficits in public institutions.[40] Such is the case of ISRA which, despite a large number of layoffs in the past few years (unskilled workers in particular), has been unable to reconcile differences in required salary expenditure and available national resources. The complete dependence on external contributions to finance programmes is unhealthy, as it presents a number of risks and inconveniences. Among the most notable are the multiplicity of foreign aid packages and their often divergent strategies. The large number of donors and their demands also lead to inefficiently large administrative outlays.

In 1986, ISRA managed thirty different grant contracts with foreign partners (ISRA, 1987). These accounted for close to two-thirds of its annual budget, while ISRA's own resources constituted only 6.8 per cent of that amount (Fondeville, 1986). The growing number of special projects giving way to particular grant contracts can also be directly traced to the erosion of the state's participation—which ISRA's directors and many foreign donors would like to see return to 50 per cent of total resources. Some donors are wondering if it would not be best to discuss the removal of aid over five, ten or fifteen years.[41]

Research expenditure as a function of GNP is largely insufficient and has been in constant decline since the early 1980s. Given the current conditions in which the state cannot increase its contribution, the Senegalese national research system must inevitably increase its reliance on foreign sources, unless it can diversify and increase the private sector's contribution to funding. Private financing (outside of NGOs) now represents approximately 1 per cent of research credits (Fondeville, 1986). Outside national or foreign private firms and foundations could be called upon to play a larger role in this area in the future. Two national foundations have some potential—the Leopold Sedar Senghor Foundation (devoted to social sciences) and the Foundation for the Impulsion of Scientific and Technological Research (FIRST). The latter is unfortunately far from attaining its assigned objectives, due in part to its failure to sufficiently distance itself from the public agencies that participated in its creation in 1982.

## Conclusion

Although the first outlines of Senegalese research institutions, that are today the heart of the structure, began to appear in the first-half of the twentieth century, the Senegalese scientific community has but a young history. While the structure of the scientific community may be characterized as nascent and formative in its present stage, the process of Senegalization began only towards the late 1970s. The University of Dakar, the first and only Senegalese university until 1990,[42] was created just a few years before independence. During its first ten years, it was attended mainly by French students. It only began to open its doors to Senegalese students after the reform of 1969, whose objective was to better adapt the content of the University's programmes to the realities of the nation and of its development. In the agricultural research sector, there has been an ongoing Senegalization of research personnel starting in 1975, the year that ISRA was founded. The institutional construction reached its apogee in 1983, with the creation of MRST. The Association of Senegalese Researchers was also created in 1983, and held its first congress in June 1985.

The operation, production and reproduction of the Senegalese scientific community remains nonetheless dependent on foreign expertise, France's in particular. Foreign dependence is especially evident in the financing of research, with external resources representing about two-thirds of the total. Although the majority of researchers are Senegalese, the research structure still hinges heavily upon the participation of numerous expatriates. Aside from a few dozen non-Senegalese Africans, these expatriates are all French. The dependence on foreign researchers, however, varies according to scientific disciplines. Senegalization advanced most rapidly in the field of health, benefiting from the creation of a school of medicine in 1918. The health sector is where Senegalese participation is most advanced. It also contains the greatest number of Senegalese researchers trained in Senegal. On the other hand, agricultural research is still very dependent on foreign sources for the training of its personnel, despite the fact that its researcher potential is high and that it accounts for more than half of the total Senegalese research funds. This situation is due in part to the fact that, until recently, a majority of the researchers in this area were expatriates. The late creation of a school of advanced agricultural learning in 1979 is also both a cause and a consequence of this excessive foreign dependence. From the overall perspective, the growth of higher S&T education structures three decades after the creation of the first full-fledged research institutions in many ways delayed the institutionalization of scientific fields and, hence, a scientific system which is sustained through a process of reproduction.

The distribution of the R&D effort among the principal sectors reveals a concentration in three main areas: agriculture, natural resources (principally environment) and health. This has not changed significantly in the last fifteen years. Applied research, particularly industrial-technological research, is the most neglected research field and is practically non-existent. The social sciences, although possessing significant research potential, are not very productive nor very visible at either the national or international levels. Productivity per researcher in general is low and the impact of research on development difficult to perceive.

Despite the valiant effort by the Senegalese government at the end of the 1970s, including increases in the research budget, the current trend is a downward one. Senegal is presently traversing an exacting period of economic crisis and budgetary rigor that is stunting the development of the Senegalese scientific community and accentuating its dysfunctions. The economic difficulties have revealed the impossibility of maintaining the growth levels of the 1970s and the need to give priority to qualitative rather than quantitative goals. In the context of austerity, the many problems here discussed will be solved only if the scientific community is able to mobilize new financial resources, notably from the private sector. There is a strong need for a national research policy that transforms Senegal's supply driven R&D system into a demand driven one. Moreover, the goal of attaining a process of complete Senegalization calls for the indigenous generation of R&D, financial and human resources to arrest the foreign dependency, which is staggeringly high at about 70 per cent presently. The modes of scientific cooperation need to be redefined in order to favour the elaboration of durable partnerships. Incentive programmes are needed to more effectively mobilize the existing Senegalese research capacities (especially at the University), to foster inter-institutional collaborations and to implement a reward system adapted to the specificities of research.

## Notes

**Acknowledgement**: The author would like to thank Alban de Fondeville for his comments on a draft of this chapter.

1. Senegal's area is approximately 200,000 sq.km. In 1985, close to 67 per cent of developing countries had a population of under 10 million and 52 per cent, population under 5 million.
2. GNP per capita in this sector has declined on average by 0.7 per cent a year from 1965 to 1987 (World Bank, 1991).
3. It would be a fruitful subject for future research to study the importance and impact of the non-governmental sector.
4. Two hundred veterinarians from the thirteen French-speaking African member states were trained at EISMV from 1973 to 1984. One-fourth of these were Senegalese, others coming from (in decreasing order of importance) Benin, Togo, Burkina Faso, the Niger

5. The University of Dakar maintained a high level of educational quality in the decade following independence, as evidenced by the equivalence of degrees with those offered by French universities. This quality has progressively deteriorated with the considerable increases in enrollment (World Bank, 1991).
6. The rate of students passing exams has been very variable: the Ecoles de Formation and the centres affiliated with the UCAD have performed better than the UCAD Schools. In the School of Sciences, the rate of success has been the lowest: 37 per cent for the first cycle and 40 per cent for the second cycle (UCAD, 1991).
7. Moving from the auspices of the Ministry of the Plan, the Ministry of National Education, and then to the new Ministry of State Modernization and Technology, DAST has suffered a diminishing of its capacities for intervention.
8. The available information about the power and activities of the new delegation at the RST is insufficient to evaluate its capacity for coordination and promotion of research. A survey was later conducted in 1985, but the data has not been accessible. Another was conducted in 1991, but to the best of my knowledge, it has not yet been compiled.
9. For example, the response rate to the questionnaires used in the 1981 UNESCO study is very low, and the resulting statistics must be viewed and interpreted with caution. According to the survey, agricultural and veterinary sciences comprise 97 per cent of Senegalese research funds. Even if these subjects account for the lion's share of the funds, such a figure is of course excessive and underlies the limitations of the survey.
10. According to officials at ISRA: 'It is unfortunately difficult to precisely estimate the scientific potential of ISRA. The requisite information is not regularly collected nor analysed. The data that we do manage to collect are not very reliable' (Faye and Bingen, 1989: 60). This attests to the difficulty in trying to qualitatively evaluate total national potential.
11. It should be noted that many ORSTOM researchers worked within the Oceanographic Research Centre at Dakar-Thiaroye (CRODT) which depends on ISRA for its funding. Those researchers manage and promote the scientific activities while also providing training for young Senegalese researchers.
12. Many observers contend that the rapid Senegalization of ISRA's personnel could only have been achieved through the promotion of many Senegalese technicians to the rank of researcher. I have not yet been able to study the validity of this hypothesis.
13. The private sector's participation is probably very limited. According to the UNESCO/PNUD survey (1985), it only accounted for 1.1 per cent of scientists involved in R&D programmes in Senegal. Most of the private research is conducted in agriculture. The Senegalese sugar company conducts its own research within the irrigated perimeter of Richard Toll, and chemical firms conduct testing independently or in collaboration with ISRA and with companies involved in product development. But some NGOs are also involved in research for technology transfer, and the research conducted in development projects should not be under-estimated.
14. The average age at ISRA in 1987 was also around 35 years. Most researchers are between the ages of 30 and 40. On average, expatriates are slightly older (Faye and Bingen, 1989).
15. The DAST report accounted for sixty-three researchers (9 per cent), while warning that this involves only national researchers and that the figure is probably under-estimated. The low student enrollments in tertiary education (4.5 per cent) reveals the weak capacity for 'promotion' in university research. In the US and in France, the percentages are 13 per cent and 9 per cent respectively (World Bank, 1991).
16. It may be that this level may have suffered slightly with the rapid Senegalization of the professor/researcher ranks.
17. Of 149 active researchers in 1987, 23 per cent had a tertiary degree or equivalent; 50 per cent had a Master's or equivalent degree and 27 per cent had a Bachelor's degree. Expatriates have a slightly lower level of university training (Faye and Bingen, 1989).
18. The DEA corresponds roughly to the first year of PhD study.

19. Others are in the United States (110), Canada (ninety-seven), Belgium (eighty-three), Morocco (seventy-one), Cote d'Ivoire (sixty-five), and other countries (246).
20. USAID, personal communication.
21. In addition, since 1983 salary expenses have been greater than the state budget earmarked for ISRA. As a result, many bonuses and allowances (annual productivity bonuses, monthly output bonuses, bonuses linked to specific tasks) are no longer offered (Faye and Bingen, 1989).
22. In 1993, the rank of researcher was created at UCAD.
23. Of the twenty-three researchers that left ISRA between 1981 and 1987, three have rejoined ministries (two of them as ministers), two are employed in other Industrial and Commercial Public Institutes (EPIC), six were recruited by private volunteer organizations having NGO status, eight work for regional or international institutions, three have gone abroad (of which two married expatriates) and one was recruited by a multinational corporation in Dakar. The number of Senegalese researchers having left after 1985 is particularly high; the turnover rate reached 18.1 per cent in 1987 (Wessen, 1988).
24. For a discussion of the question of measurement and evaluation of scientific productivity in LDCs, and more particularly of the pertinence of scientific indicators for LDCs, see Arvanitis and Gaillard (1992).
25. The ISI indexes approximately 5 per cent of the 70,000 scientific journals published in the world. These are the most frequently cited journals (or mainstream science) which are found for the most part in journals published in the industrialized world.
26. See also the chapter on Nigeria in this volume.
27. The PASCAL database was consulted for 1975, 1980 and 1985. Although it is more exhaustive than CSI for French-speaking countries, it displays certain inconveniences. It is only possible to extract publications whose first authors have an institutional address in Senegal. In addition, in the late 1980s, with the move of the database from Paris to Nancy, many dysfunctions were found in the indexation of references. Finally, social science references are not included in PASCAL. They are contained in the FRANCIS database, which was not consulted for this study.
28. In the following analysis, only references in which the first author claimed an institutional address in Senegal were included.
29. The decrease between 1975 and 1985 can be attributed to the integration of some of its researchers (mainly oceanographers) into ISRA during that period. Their publications were counted with those of ISRA as of 1980. What is more, many ORSTROM researchers work within the University, the Institut Pasteur, the Organisme de Recherches sus l'Alimentation et la Nutrition Africaines (ORANA) and the Ecole Nationale Supérieure et Universitaire de Technologie (ENSUT).
30. Research in this area is often the product of doctors at the Hospital of Dakar and that of the UCAD School of Medicine. It often takes the form of brief notes by multiple authors.
31. This is the field of predilection for ORSTOM researchers.
32. This dependence would be even greater if the references concerning Senegal indexed in the PASCAL database were included. During 1988, there were ninety-seven references about Senegal, of which the first author did not reside in Senegal. Aside from the authors of a few Senegalese theses, most of the other authors were French or (to a lesser degree) American.
33. The average number of authors per paper was particularly high in 1985 (3.45). In certain fields such as health, and especially clinical research, some publications list up to ten authors, sometimes even more than ten.
34. In the School of Arts and Human Sciences, only the Department of Geography publishes bulletins regularly (TECASEN and LABOGENU). The latest issue of the Senegalese Journal of History was published in 1981 (Richard, 1988).
35. Expatriate French researchers generally publish in the journals of their home institution (ORSTOM, CIRAD, IPOM, etc.).

36. See ISRA (1988). This bulletin is the first product of the operation begun in 1988 to evaluate the global production of ISRA.
37. The 1958–1979 Agricultural Plan consisted essentially of appropriating credits and subsidies to farmers for the acquisition of agricultural equipment, inputs (fertilizers and fungicides) and high yielding varieties of seeds (principally groundnuts).
38. The main goal of the New Agricultural Policy is to achieve 80 per cent self-sufficiency in grain by the year 2000. It also seeks to promote the diversification of agricultural export products to improve the balance of payments.
39. The analysis of agricultural research funding by the World Bank (1982–1988) reveals a similar distribution. Senegal's estimated portion of 33 per cent at the beginning of the projects has only fallen to approximately 30 per cent in 1987. France's share is 33.5 per cent, of which half is devoted to remunerating expatriate French researchers.
40. Paradoxically, the World Bank, which had required the state to reduce its spending, has laid out among its conditions for the renewal of the Agricultural Research Programme in 1989 that the Senegalese government re-establish its budgetary contribution to ISRA to its 1983 level, or 1.45 billion CFA (World Bank, personal communication).
41. USAID, personal communication.
42. A second university was created in Saint Louis in 1990. Six hundred students enrolled for the first year.

## References


**Arvanitis, R.** and **J. Gaillard** (eds.) (1992). *Sciences Indicators for Developing Countries.* Proceedings of the International Conference on Sciences Indicators for Developing Countries, ORSTOM/CNRS and UNESCO, 15–19 October 1990. Paris: Editions de l'ORSTOM.

**AUPELF** (1984). *Répertoire des Enseignants et des chercheurs africains, Université d'Afrique membres de l'AUPELF.* Paris: AUPELF.

**Braibant, M.** (1986). 'Politiques macro-économiques et performances agricoles au Sénégal, 1960–1984'. Thèse de Doctorat de 3ème cycle en économie du développement. Paris: Université de PARIS I.

**Centre National de la Planification de la Recherche Scientifique (CNPRS)** (1973). *Analyse du potential scientifique et technique au Sénégal.* Dakar: CNPRS.

**Clozel** (1916). 'Circulaire au sujet de la création d'un Comité d'Etudes Historiques et Scientifiques de l'AOF', *Ann. Mém. Et. Hist. et Sc.* Dakar: AOF.

**Cornevin, R.** and **M. Cornevin** (1964). *Histoire de l'Afrique.* Paris: Petite Bobliothèque Payot.

**DAST** (1991). *La recherche à l'Université.* Dakar: Ministère de l'Education Nationale.

**Davis, C.H.** (1983). 'Institutional Sectors of Mainstream Science Production in Sub-Saharan Africa, 1970–1979: A Quantitative Analysis'. *Scientometrics*, 5(3), 163–75.

**Faye, J.** and **R.J. Bingen** (1989). *Sénégal: Organisation et Gestion de la recherche sur les systèmes de production.* La Haye: ISNAR.

**Fondeville, (de), A.** (1986). 'Communication sur le financement de la recherche'. Colloque sur la gestion des systèmes de recherche du Sénégal, 23–27 juin.

**Gaillard, J.** and **R. Waast** (1992). 'The Uphill Emergence of Scientific Communities in Africa'. *Journal of Asian and African Studies*, 27(1–2), 41–67.

**Gillet, J.E.** (1976). *Analyse du potentiel scientifique et technique au Sénégal (1975/1976).* Dakar: DGRST.

**Gleizes, M.** (1985). *Un regard sur l'ORSTOM 1943–1983.* Paris: Editions de l'ORSTOM.

**IFAN** (1961). 'Historique de l'Institut Français d'Afrique Noire'. *Notes Africaines*, 90, avril.

**ISRA** (1987). *Stratégies et Programmation des Recherches 1989–1993.* Dakar: ISRA.

——— (1988). *Bulletin Analytique Documentaire—Année 1986.* Dakar: ISRA.

**Jiminiga, S.** (1986). 'Forces et Faiblesses d'un système'. *Afrique Nouvelle*, 1er octobre.

**MRST** (1984). *Le Centre National de Recherches Agronomiques de Bambey*. Dakar: MRST.

**Ndiaye, G.H.** (1988). 'L'Evolution des Structures de la Recherche au Sénégal', in Gaillard, J. (ed.). *Politique, Programmation, Gestion de la Recherche pour le Développement*. Paris: IIAP.

**Niang, S.M.** (1987). 'Africanisation Totale du Personnel dans trois ans'. *Le Soleil*, 4 janvier.

**Richard, J.** (1988). *Compte Rendu de Mission au Sénégal*. Paris: Ministère de la Coopération.

**Sene, D.** (1985). *Etude de l'impact de la recherche agronomique sur le développement agricole au Sénégal*. Paris: CIRAD.

———. (1987). *Aperçu des technologies agricoles disponibles au Sénégal*. Paris: CIRAD.

**Sylla, Y.** (1986). 'La situation de la recherche au Sénégal et le statut du chercheur'. Lecture given on 18 January at Ecole Normale Supérieure, Dakar.

**UCAD** (1991). *Rapport Annuel pour la rentrée universitaire 1991–1992*. Dakar: UCAD.

**UNESCO** (1985). *Annuaire statistique 1985: III-427*. Paris: UNESCO.

**UNESCO/PNUD** (1985). 'Inventaire du Potentiel Scientifique et Technologique de la Communauté Economique de l'Afrique de l'Ouest (CEAO)'. Projet PNUD RAF/78/067. Paris: UNESCO.

VIIème Plan de Développement Economique et Social: Orientations et Programmes d'Actions Prioritaires, 1985–1989. *Nouvelles Editions Africaines*. Dakar.

**Wessen, P.D.** (1988). 'Causes and Impact of Turnover of Research Scientists within the Senegalese Agricultural Research Institute (1981–1987)'. MSc Thesis. Lansing: Michigan State University.

**World Bank** (1986). *World Development Report 1986*. Washington, DC: World Bank.

——— (1989). *Staff Appraisal Report, Senegal Second Agricultural Research Project*. Washington, DC: World Bank.

——— (1991). *Revitalizing Higher Education in Senegal, The Challenge of Reform*. Washington, DC: Population and Human Resources Department, World Bank.

**Zymelman, M.** (1990). 'Science, Education and Development in Sub-Saharan Africa'. World Bank Technical Paper: 124. Washington, DC: World Bank.

# 7 Science and Technology in South Africa: A New Society in the Making[1]

**Jean-Baptiste Meyer**

> Dr Franz-Joseph von Leinsdorf is [a scientist] absorbed in his work; wrapped up in it, as the saying goes, year after year the experience of this work enfolds him, swaddling him away from the landscapes, the cities and the people . . . .
>
> The shortage of skilled manpower brought about his recruitment here [in South Africa]. He has no interest in the politics of the country he works in (Nadine Gordimer, *City lovers*).

South Africa is in a period of transition[2] between two states of society: one obsolete and on the way out, the other under construction and on the way in. With the dismantling of the former regime and the difficult assembly of a new one, this intermediary period is proving decisive. Socio-political analysis shows how the discarding of the institutional rules of apartheid is also wiping out the reference points, values and norms that used to be the Draconian gel of a certain collective order (Darbon, 1992; Darbon and Faure, 1992). Decomposition, decay and disintegration are among the terms used to describe this situation.

South Africa is not solely in the grip of *centrifugal* forces. This period of transition is also being propelled by centripetal movements or, to put it more precisely and in a less mechanistic manner, 'decomposition-reconstruction' dynamics with the involvement of fully-fledged actors (Copans et al., 1992). Cultural groups, trade union organizations or civil rights associations, for example, are becoming attached to establishing new cohesive bonds; through the associations they implement and the emerging 'social networks', they are progressively weaving a new societal fabric.

This article intends to do its part towards the description of the reconstruction efforts by drawing attention to the ongoing action in a still unexplored yet vital sector—science and technology—which should be studied as cultural constructions closely related to the society producing them and whose sense of meaning they influence. They actually translate social conditions, while at the same time creating them too. S&T proceeds, in fact, from negotiations and the balance of power between entities—in short, from associations of people and materials. Yet, they also shape the intellectual and physical world that constitutes, and is indissociable from, society.[3] This 'constructivist'[4] approach fittingly accounts for the current changes in South Africa. In revealing the actors-builders' blueprint, it above all enables us to outline the main themes of the reconstruction.

This chapter is divided into three sections. The first highlights the importance and characteristics of South African S&T research. The second shows its place in a social plan and how it is laying the foundations for the future. The third introduces its effects on pan-African industrial innovation and socio-economic development—levels where the very identity of South Africa is being redefined.

## A Historic Turning Point for South African Research

It would be illusory to try and present an exhaustive report on the S&T system of South Africa. Just as with the country itself, the transitional and much debated situation characterizing it cannot be captured in a supposedly objectivizing portrait. Respecting this relative and temporary state of affairs, our adopted methodology deliberately works from two separate standpoints: one bringing out the sturdiness of the system and the other, its weaknesses. Together, they will produce a picture highlighting the contrasts of the S&T landscape. This blended vision will help relocate the system with regard to its economic, political and other stakes—in short, contextualizing it, like any other social and historical phenomenon.

### An African Giant

There is no common measure between the research machinery of South Africa and that of other countries on the continent. For instance, it is often hard to know whether South Africa belongs to the category of developing countries or not: looking at its GDP one would be inclined to say no; yet, its structure and arrangement firmly suggest that it does. On the basis of scientific indicators,[5] the Republic of South Africa (RSA) would unquestionably figure as an industrialized country. In terms of contributions to world scientific production, as recorded in major American databases, it is ranked twenty-second, which is entirely respectable considering the country's size (Pouris, 1989). The local scientific establishment underlines this fact, comparing its research capacity with big Western countries rather than its African neighbours. True enough, the RSA alone produces a quarter of all the African scientific publications registered by the bibliographical databases. And the proportion is even greater in the area of hard sciences. Its many abilities cover a whole range of areas from all the natural and social sciences through to aeronautics, telecommunications, science of materials and genetic engineering. The indicators show a considerable gap between the RSA and the next biggest country in Africa: Nigeria has five times fewer engineer-researchers and invests three times less of its GDP in research. And the configuration for Kenya, the third biggest country on the continent in this respect, is comparable to that of Nigeria (Pouris, 1991; Gaillard and Waast, 1992).

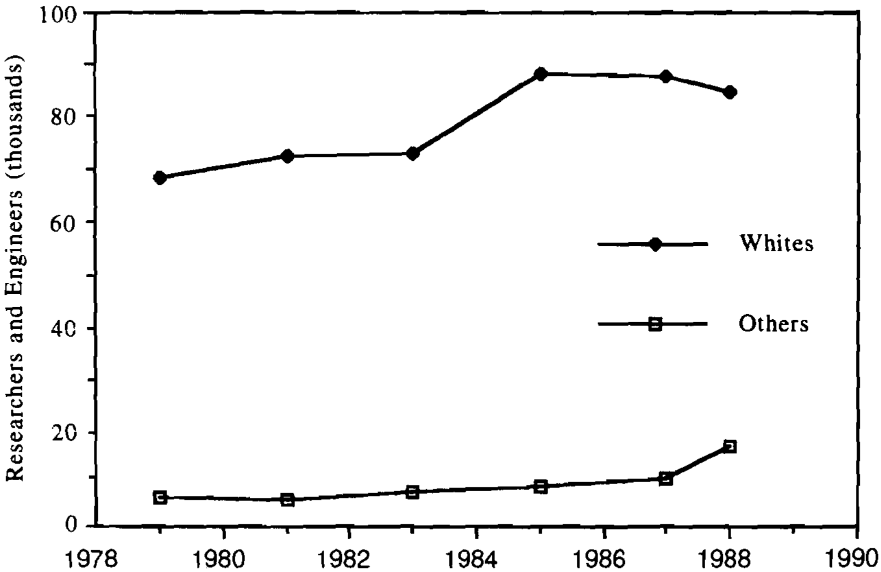
The scientific dividing line between the RSA and the rest of Africa is drawn on the basis of indicators that, somewhat ambiguously, reflect a particular form of research activity rather than a universal and homogeneous science. Some of the leanings of the international publication databases are now well-known: they implicitly record references more to do with a mainstream, mainly Anglo-Saxon, science while under-rating the locally edited production characterizing research in the Third World (Gaillard, 1989). Also, in describing Third World research on the basis of such indicators, South African research managers are in fact endorsing the criteria prevailing during their construction. They are not describing an absolute position for a system which is measurable and naturally commensurable to others; they are emphasizing a significant inter-comparability between mainstream science and their own. The phenomenon is indeed worth pointing out. It illustrates the socio-cultural nature of scientific activity whose 'modes of circulation', 'visibility' and 'style'[6] in the RSA bring it closer to that practised in big Western countries. Explanations for this can doubtless be found in the history of the South African scientific community. The fact that young researchers have frequently trained at British, Flemish or American universities, for example, most certainly has something to do with it. But we do not need to delve into the past. Determining the extent to which racial divisions still underlie the make-up of research staff today is convincing enough evidence of the meaningful social moorings of local science (see Figure 7.1).

The graph shows the overall magnitude of the gap between researcher-engineer racial populations as well as the recent trend to close it, which has amplified since the period considered here.

The institutional configuration of the South African S&T machinery is modelled on the traditional British pattern. Statutory councils manage and carry out research along the lines of divisions in large, very distinct sectors (see Figure 7.2). They employ a good many researchers in work that they lead for themselves. A significant part of their budgets nonetheless serves to finance outside (private or university) individuals or groups brought into their broadly selected and coordinated projects. So they deal with two branches of activity at the same time: one purely investigative, and the other administrative and tied in with science policy (see Figure 7.2).

Even before the recent political change, the machinery had been undergoing change for some years with the government instructing the councils

FIGURE 7.1
Number of White Research Staff Members and Others

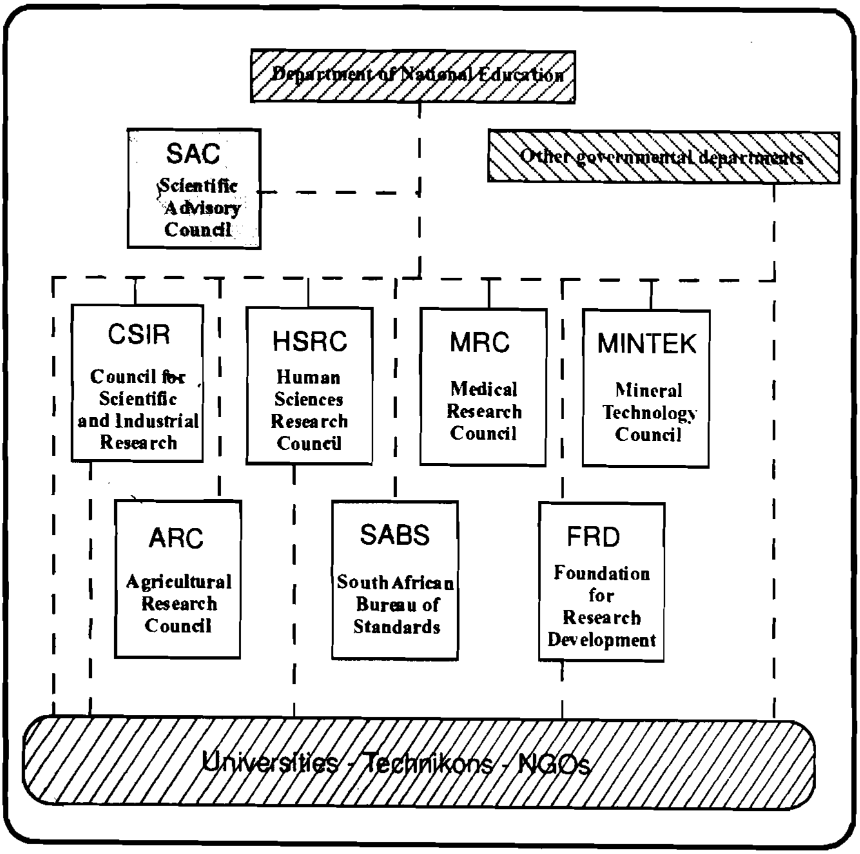



Source: Central Statistical Service, Manpower survey[7]

to take on greater financial autonomy since 1988. This was the 'framework of autonomy': a planned, yet rapid, state disengagement from the funding of activities of national scientific bodies.

Research policy had always previously been subject to voluntarist state-led action, managed by an 'interventionist' bureaucracy and organized with massive public investment. So why such a change? There is much more to it than just economic reasons or the need to relieve the pressure on state budgets in a period of economic crisis. On one side, the former regime's vital requirement to keep close and exclusive control over the basic power source disappeared as soon as the democracy process got underway. Elsewhere, the independence prepared by the 'framework of autonomy' was a way to protect its institutions from being called into question with the change of government; and there were people who were keen on keeping

FIGURE 7.2
Organization Chart of South African Research



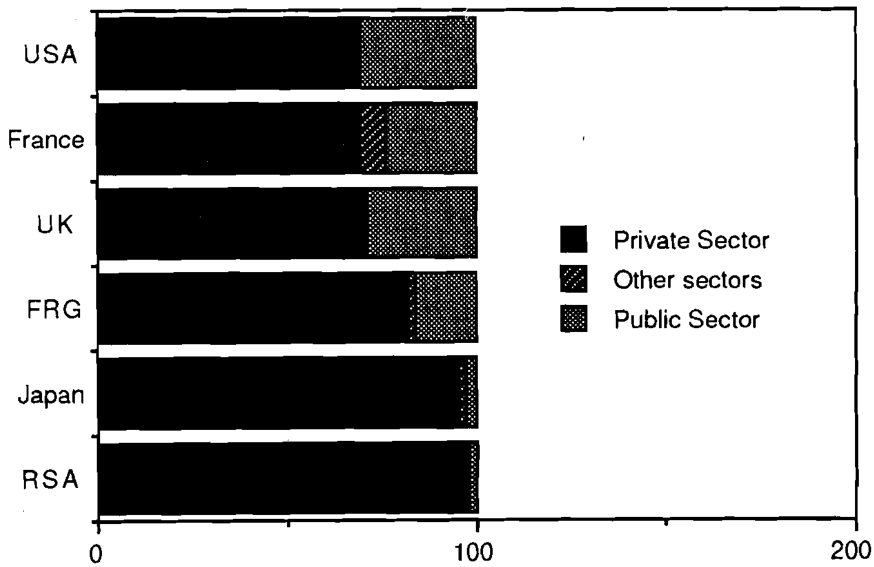

an outstanding, yet fragile instrument (that is, the South African research machinery), from falling into 'unsafe hands'.[8]

## The Fragility of R&D

The research system's weaknesses can be seen not so much in its rather complete and diversified internal architecture as in its linkages with economic production and education in schools, colleges and universities.

First, we see the pronounced division between public research done by both the earlier-mentioned bodies and the universities, and the equally important research accomplished by private firms. The public sector contributed very little to the R&D of companies (see Figure 7.3) and they, in turn, hardly played any part at all in the investigative activities of

**FIGURE 7.3**
**Company R&D Funding Sources**




Source: OCDE, 1986[12]

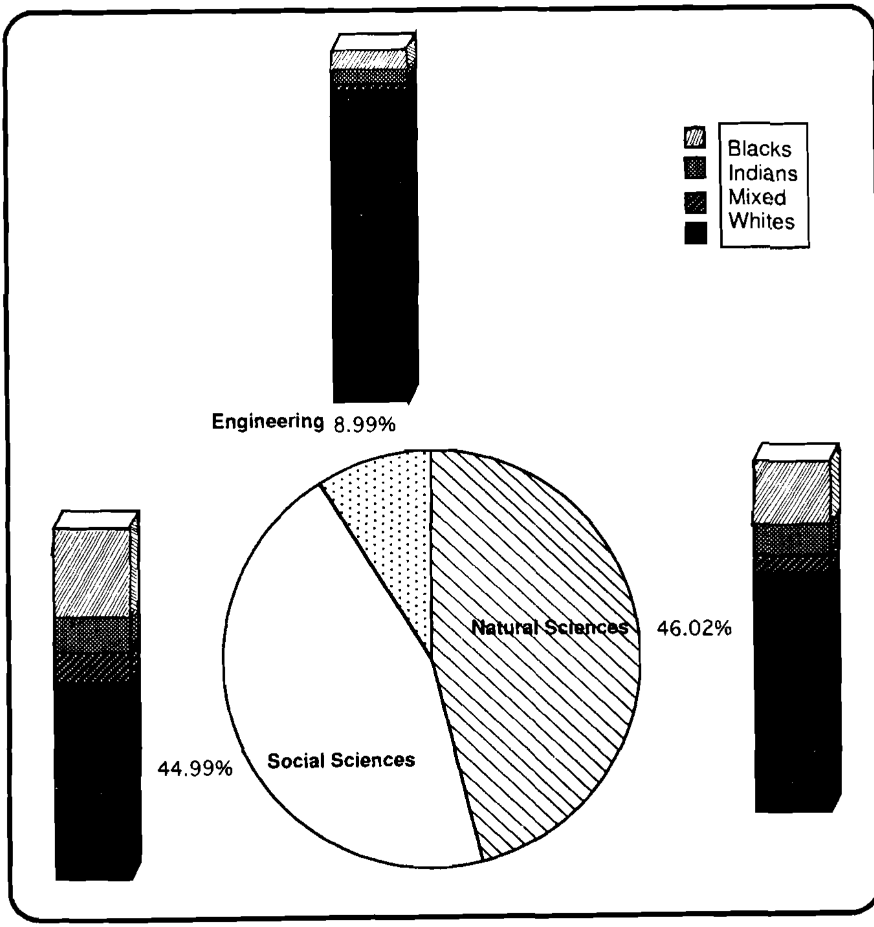
public bodies prior to the recent age of autonomization. The fact that the two sectors are so completely out of joint is highly detrimental to the revival of the industrial system and, consequently, to economic growth. What the strategists of innovation in the RSA currently deplore is the absence of a technology policy and the difficulties involved in transferring science on to the market.

Over the past few years, an unfavourable economic trend has been setting in. The causes of the decline are many and much debated. Sanctions may be the more familiar of them, but they chiefly seem to have interacted with other phenomena, both circumstantial (e.g., droughts, falling gold prices) and structural (especially industrial obsolescence).[9] One identified factor is the drop in industrial productivity. Some studies point out that the apartheid system has left the work force deskilled and demoralized; others refer more to the run-down equipment, antiquated manufacturing structures and the collapse of competitiveness (Harary and Beaty, 1989). In fact, the causes appear to be combined, often indistinct, cumulative and reciprocal—the crisis might be more precisely of a 'socio-technical' order (Gelb, 1991).[10] The production system's failure to generate the innovations it needs to remain competitive is especially due to the apparent shortcomings of the techno-economic networks. There is a 'technology' pole missing between the poles of 'science' and 'the market',[11] that is, the capacity, abilities, organizations and equipment able to design, test and develop artefacts in a collective and repeated process of innovation. The make-up of the South African R&D work force ostensibly confirms this fact: there are comparatively fewer engineers than researchers and their proportion has significantly diminished throughout the last decade, which saw a coinciding fall in the country's industrial production. It is a telling correlation which has drawn attention to some of the weaknesses of the South African education system.

Two avenues of technological training exist in South Africa, in two different types of institutions: universities and technikons. Technikons are colleges of higher education that aim to produce technicians specialized in various branches of industry and the service sector. Graduates should, in theory, eventually become the vital, highly-qualified employees that a highly technology-intensive production system on the lookout for planners has long been awaiting. Until now, technikons have, in reality, been considered as the poor relations of higher education: their teaching staff, resources, student numbers and the status of their diplomas are traditionally regarded as being of a lower quality and level than the universities. The universities, for their part, are unable to compensate for the lack of intermediary training in the education system. In fact, they themselves have to face their own shortcomings in terms of low numbers of engineering students. Exactly how low they have fallen and the manifest asymmetry between training in engineering and in the natural sciences can be seen in the graph in Figure 7.4. The imbalance is all the more striking when the socio-racial characteristics of student bodies are taken into consideration. Extremely few coloured teachers would be in a position to take charge of sophisticated technical activities, if there were no marked and rapid shifts in the trend.

The very low level of education in majority of the population seems to be a crucial problem for the development of South Africa (NEPI, 1993). And it has an effect on the numbers of researcher-engineers per social group. If the country wants its research system to be representative of the population and concerned with its development, its S&T staff has to be diversified. Yet, the pool of brains trained to undertake this is still very much dominated by a single colour: it is impossible to enrol fewer people from the Black, Mixed Race and Indian groups. Efforts in their school

FIGURE 7.4
**Distribution of Students Per Sector and the Proportion of Whites, Indians, Blacks and Mixed Races in 1988**




Source: Department of Education[3]

environments to raise awareness of the natural sciences and encourage familiarity with technology are embryonic.

The machinery of South African S&T is indissociable from the social, political, economic, educational and cultural challenges, many of which it also brings to light. Aware of its robustness and size, as well as the weakness of its training capacities, some actors have introduced it into the reconstruction debate and their social plan for a new South Africa.

## Science and Technology Enter the Debate

In South Africa today, S&T creates a space where positions are taken up, interests are vested and stakes defined. Research is not just instrumental in the establishing of a new society. It is also fundamental or foundational insofar as it is where future solutions are tried out, and active forces express themselves and are tested. In such a climate of strategic positioning, some inspired actors are themselves creating the events that will enable them to acquire and consolidate their positions.

### Strategic Deployment and Tactical Initiative

Research in South Africa is currently effervescent. One of the underlying reasons is the application of the earlier-mentioned 'framework of autonomy' which has caused great changes in the institutional and financial structures. Yet, there is also the fact that research is deeply affected and concerned by the ongoing transformation. Better still, because it draws up scenarios for the future, it plays a lead role in offering propositions. The preoccupation for research in the political debate grew alongside the feeling that the regime was about to change. A variety of different initiatives saw the light of day before F.W. de Klerk took office, and have proliferated since.[14] One of the initiatives that emerged was a complete mobilization of the research system through the unprecedented politicization of S&T issues.

The democratic movement, a three-headed actor made up of the African National Congress (ANC), the COSATU group of affiliated trade unions and the South African National Council (SANCO) civil rights association, has sparked off a procedure subjecting the research system to constructive in-depth review. The initiative first consisted of assessing the institutional and organizational machinery of S&T, and then discussing its results with the people involved. The idea of an in-depth examination followed-up by an exchange with the people in-charge was put into practice with consummate diplomatic skill. Instead of directly opposing the upholders of the South African scientific establishment, the democratic movement brought in an initially fully credible third party—a panel of British, Canadian, Kenyan, Swazi and Jamaican experts—who did the assessment in line with an OECD-applied methodology ratified on the basis of a good number of earlier exercises in other countries and clarified at the outset. The operation received funding and support from the IDRC. The self-regulating, independent assessment mission lasted for fifteen days in December 1992. It visited all the main scientific and research organizing institutions, interviewed their managers and went through descriptive documentation. Its members then went on to analyze the data and write up a report entitled 'Science and Technology for a Democratic South Africa' in February 1993,[15] copies of which were sent out to all the institutions they had visited. Their managers then had the chance to present to the panel their reactions for its advice at a one-day meeting held at the beginning of March. This top-level meeting constituted a truly historic event: it opened the first genuine forum for first-rate dialogue on research.

Before going into what the experts actually said, it is important to stress the effectiveness and reach of the method used. First of all, the evaluation exercise came off perfectly, with as full a review of the whole system as had been planned within the allotted time. Second, not a single institution nor South African research actor evaded or excluded themselves from the process at any time. Finally, following this first effort, the ins and outs of the system underwent a wholesale return to the drawing board. Research organization and its vocation came to form the subject of broadened and formalized public discussion. None of this had been sure-fire in advance; far from it. It was the first time that the managers of S&T had assembled (collectively and before witnesses) to consider the future role their fields should play in a democratic society. This consequently expressed a politicization of the field, enacted in a cool-headed, well-mediated fashion via a technical/managerial assessment exercise by an actor expected to bypass ideological meaning and personal interests and still get to grips with the most sensitive strategic issues. This assessment–discussion constitutes a really historic event that has had three effects:

- Research is no longer considered as an extra-social activity or one that transcends policy. On the contrary, it is recognized as being crucial and central to the development of the community in which it plays a part.
- Scientists are being called down from their 'ivory towers' to enter the social arena; although they undergo questioning there, they also negotiate their roles and acquire a formerly eclipsed dimension.
- The director staging this scenario becomes an unavoidable actor, an obligatory passage point in the emerging situation.

This last point deserves some attention, for it helps us to grasp the ongoing action and understand it without having to resort to outside explanatory factors. With this initiative, the democratic movement did in fact take on the role and status of a near-official interlocutor for South African research operators. Is this simply the conversion of symbolic capital acquired elsewhere and carefully reinvested here, just as S&T takes on fresh importance? Might it be a pure extension of the political field into a space naturally reinterpreted according to the new deal of the cards?[16] In reality, it is a more subtle phenomenon than that. There is far more to it than porosity between compartments of a multiple social reality or *political* overdetermination vis-à-vis the rest. The actors' genius in creating events and making history is what is at work here. Before them, science received no official recognition whatsoever from the powers that were; it existed, of course, but only for itself, disconnected from the social issues to which it could never manage to make any more than a marginal contribution. Prior to the democratic movement initiative, though, could a scientist accept a politician as an able judge of research—especially anyone from precisely that militant movement? Actually, in this unprecedented relationship, it is politics and science that are being altogether reinvented through the mediation of the panel. For the process to succeed, the actors too have an interest in this redefinition, this new plan for sharing out status, abilities and attributes. The democratic movement is imposing itself on the scientific community as an unavoidable, skilled, de facto representative; indeed, not a single top-level manager withdrew from the assessment exercise or contested its good grounding. Conversely, the democratic movement has implicitly given institutions (issuing from the former regime) a central role and an ability to take part in working out the new South Africa.

This outline picture does not portray an irenic landscape, a consensual situation. One of the people involved, as it happens, has perfectly summed up this meeting as a 'marriage of convenience, not love'. The negotiations are indeed bitter and the legitimacies unstable, even hotly disputed. Research institute managers, for example, are calling for private sector speakers and representatives from other political movements to be brought into an 'inclusive dialogue process'. Meanwhile, the ANC laid the blame for the current crisis on the scientific managers so as to incite their obedience. In short, while there may be mutual recognition between the two parties, there is also continual bargaining over the bases of that recognition and the sense of authority.

## Denunciation and Construction

Launching a public debate about research based on an assessment of the existing machinery is far from just a symbolic gesture; it has opened up a path to a critical, well-documented and argued report on the state of the system and its vocation. At the same time, this review work has been backed up by an effort to make concrete proposals; here again concerning both organizational and institutional layouts, and the deep-seated scientific and technical orientations of the programmes.[17]

The assessment brings one of the South African scientific community's old-fashioned attitudes right up-to-date. The community used to like to represent the world of research as a 'republic of science',[18] governed by purely intellectual and apolitical laws, and totally foreign to social life. The ANC refuses such an exoneration of responsibilities in contemporary historical phenomena and, on the contrary, urges research officials to assume them entirely. In so doing, it is paradoxically reassuring the scientific community by expressing all the respect it has for their activities. Indeed, the ANC maintains it will give research a central place in the very areas where scientists feared it might tragically lose out to socio-economic priorities (teaching, basic healthcare, employment, etc.). It has stated that rather than the question of a choice between healthcare and research, for example, the latter will be used in the development of the former. In fact, if the citizens of the 'republic of science' had been 'waiting for the barbarians',[19] they have found to their relief that the people they are dealing with intend to safeguard many of their treasures. The democratic movement recognizes the quality and consistency of the country's S&T machinery; there is nothing like it anywhere else in Africa. It maintains a wish to thoroughly transform it, yet also to keep what is good. While this (cautious) discourse is clearly not without ideology, it is above all else the pragmatics of action that clearly show through.

One major point of discussion has been the power to decide in science policy matters. The assessment mission denounces the 'policy vacuum', the dissolving of responsibilities and the absence of strategic perspectives in matters to do with the country's research. Many opinions converge on this. This opaqueness, the vagueness, and the inconsistency and incoherence in decision making are forever cropping up in comments describing the current situation. Simply a problem of bureaucratic management? That is not the way the ANC, for example, sees it. Their analysis explains the state of affairs historically. The 'policy vacuum' is a recent phenomoenon, stemming from the socio-political transformation of the South African state. With the abandoning of apartheid, the systematic security policy would become useless and drained of one of the major secret components of its vocation: the techno-scientific apparatus. Deprived of its centre, the backbone linking it unofficially yet effectively to a coherent policy, it would lose its sense of direction. The democratic movement tends to counter this by reallotting it a very strong social meaning—this time official and in response to the needs of the majority of the population.

The democratic movement's analysis stands as a shining example of the problematization of a situation.[20] Starting with a well-constructed report and formulation—the 'policy vacuum'—one ends up reconsidering the very foundations of the system. This approach does not meet with the automatic approval of all the actors. Some judge the 'policy vacuum' to be a rhetorical formula describing a situation they consider to be far less alarming in reality. Others recognize the vacuum, yet put it down to different origins: the 'framework of autonomy'. They go on to attribute inoffensive consequences to it: this decentralization plan would mean flexibility and independence more than indecision or incoherence. Finally, still others express doubts about whether it is possible or relevant to align science with a population's needs; it would appear to be an unnatural marriage likely to destroy the performance of the South African system.

Despite the alternative visions, the majority of actors converged to the democratic movement's general option. Most top-level managers of public research institutes subscribed to the idea of re-orienting the research system towards matters concerning society as a whole. This was no magical convergence; rather, it was the result of careful groundwork on the part of the democratic movement: the assessment exercise, the public nature of the meeting, its very title and the preparatory documents defining the main lines of discussion—all points that both created and contained the area of debate. The fact that S&T and its problematization with regard to socio-political issues are now subject to discussion is well and truly the fruit of constructive work.

In the end, the collective negotiation exercise instituted the needs of the majority of the population as a fundamental priority in reconsidering a system. The whole matter then became one of identifying those needs and the ways to meet them. On the organizational and macro-social level, the required changes would seem clear. First, there was no avoiding a change in resource allocation. The highly research-intensive, sophisticated military technologies (the pride of the South African 'military-industrial complex') will have to have their scientific and economic facilities partially turned over to more constructive ends. So, the symbolic shift from security to development options is thus plain to see. Yet, for all that, the practical difficulties have not been eclipsed: many actors present the reconversion as requiring time and a well worked-out strategic definition. Another sector closely related to this has also been put on the hot seat—the nuclear sector. The Atomic Energy Commission, which manages the South African nuclear programme, appears to be an efficient institution; yet it is expensive. Although its reactors are running well and giving full satisfaction, it costs the government 700 million Rands a year to produce nuclear fuel or goods that will be worth no more than 220 million within a matter of four years.[21] It has to be reassessed according to technical, economic and political variables that hardly make a very favourable case: availability of coal reserves, the hydroelectric potential, and the disappearance of the security argument and force-related legitimacy. Orienting a system adapted to serve the minority is discussed with just as much severity. The assessment mission cast doubts on whether the upkeep of costly equipment, such as the particle accelerator—the finest jewel of a luxury techno-science rather than a public utility—is appropriate. In most cases, unbearably high-cost end applications, like nuclear cancer treatment using the accelerator, concern a proportionally small, privileged section of the population. Meanwhile, developing more primary medicine for categories of people deprived of healthcare structures would constitute a more judicious use of the same resources. Therefore, at the very heart of the systems being planned, there are highly political priorities at stake where the choices clearly involve a vision of society.

Whereas re-orienting the system towards the needs of the majority appears to be a concrete and syncretic objective, identifying them is proving complex. Some researchers say they need to be translated into an understandable demand. So who is best fit to do the translating? Which actors represent the majority? Who can set forth the needs calling for an element of research, according to individual cases and in various fields?[22] Everyone, in fact, agrees that the population's living conditions appear so heterogeneous and misunderstood that the demand can only come to light via credible intermediaries. Here again, introducing legitimate representatives is most easily accomplished at the institutional level. Suggestions with regard to this have been issued by the democratic movement. With the statutory overhaul of their boards of governors, the councils should be able to quickly open up and reflect racial and social plurality at this level. Affirmative action to recruit non-white researchers at the research operator level already seems more problematic. Systematic application in fields, where exceptional rather than interchangeable actors are by definition crucial for building and retaining ability, is not helped by the difference in training levels between Blacks and Whites. Consequently, it has become an essential objective to reform the education system, and both the teaching and widespread cultural dissemination of S&T among the population. This involves long-term change; science here is no longer in the unilateral service of society: the latter has to meet the demands of the former—a reciprocal arrangement. This two-way movement is also expressed in attempts to define the representation of demand. As such, in think-tanks, actors from civilian society, the unions and associations often emerge as the most credible representatives of majority needs and the intermediaries between those needs and the science producing the innovations intended to meet them. Now the sphere of association and union is showing itself to be indulging in intense training and research activity, and clearly anxious to understand and manage S&T developments.[23] These are plainly central to the development perspectives now being freely considered with regard to Africa as a whole.

## An African Avenue of Development

'New South Africa' intends to take up a totally different position in the international community. Rather than just a matter of an inevitable opening up with the lifting of sanctions, or a blind belief in doing so, this is a matter of South Africa genuinely redefining its status and role within that community. S&T innovations allow one to put forward an explanatory hypothesis on the ongoing changes, bringing them into a long-term historical perspective.

## A Policy of Innovation for a New Identity

South Africa is changing references: it sees itself less as a real industrialized country and more in a state of development. This is patent in both the discourse and strategies induced by that change of reference. In finally recognizing the 'African' majority of its population, the country is also reconsidering its enrollment into world society. In reducing its 'European' ancestry to a minimum, South Africa is partly identifying with other Third World countries and with its African neighbours. Its ongoing internal reassessment is coupled with external repositioning in the international networks. In the scientific and technological fields, this phenomenon is being expressed in a particularly acute fashion.

The public bodies, chiefly HSRC, Medical Research Council (MRC) and CSIR, are drawing up programmes with an emphasis on 'community problems'. Their referent for naming, designing and organizing programmes thus becomes the Black population, in the generally perceived and accepted sense of the term. This designation is accompanied by a cognitive change of which the bodies are aware: many community-related problems need new categories of learning, new methods of work and new conceptual tools. Research bodies are increasingly opening up to the international sphere, chiefly with a view to equipping themselves or perfecting their abilities in those areas where tropical and *tropicalist* institutes operate.

In considering the problems of illiteracy, agricultural food production, hygiene and the environment, the public institutes are picking up on experiments conducted elsewhere in Africa and issuing proposals for the continent as a whole. The case of CSIR speaks for itself; it has been developing an authentic African sector of activities, coordinated by an 'African business development' director. This is essentially a matter of a programme applying South African expertise to development projects. Chiefly financed by multilateral agencies, these are already stretching well beyond southern Africa to the fringes of French-speaking Africa. There is obviously a higher concentration of efforts in the former though. For example, the electronic network starting in Pretoria with international connections via the Cape, has linked the country's academic community with its counterparts in the big OECD countries and also its immediate neighbours, who were actively encouraged to plug in. Regional cooperation in the actual managing of research is intensifying at a very fast rate. In June 1993, the FRD held a conference in Pretoria in conjunction with the United Nations African Economic Commission and the Organization of African Unity (OAU) under the title 'Development of a Sub-Regional Science and Technology Policy in South Africa'. All these initiatives go hand-in-hand with, and very often precede, the growing attempts at regional reconciliation, be they commercial or otherwise.[24]

The rest of Africa expresses a firm interest in seeing the country extend the benefits of its abilities throughout the continent. The panel of the reassessment mission, by the way, recommended that South African researchers become more involved in the continental scientific community. In January 1993, the first round table of scientific advisors for 'science-led development in Africa' was held in Nairobi. Its theme was 'Managing Science and Technology for the Rapid and Sustainable Development of Africa'. South African representatives, from non-governmental academia, received their first ever invitations to attend. Their colleagues showed how keen they were on seeing South Africa play an active part in the endogenous continental constitution of the science-led development base, without excessive interference on the part of non-Africans. Considering the call for a repeat of the exercise, even at the governmental level, this kind of approach has every chance of being developed in time. The country's research capacity is consequently acting as a real catalyst for the African scientific community.

The Africanization of the mode of development is particularly strong in the linkages between S&T policy and industrial growth policy. In the face of the structural problems confronting the South African economy, there is agreement on the need for industrial redeployment. The whole question is to determine the branch, subjects and methods to adopt. Two possible strategies have been put forward: one favours industrialization based on internal markets or 'inward industrialization'; the other, on the contrary, is 'export-oriented', recommending the production of goods and services for export.[25] Actually, a synthesis of the two options is emerging with a judicious international arrangement in the bargain. This involves identifying the sectors where goods satisfying an internal demand are also suitable for the international market. This is especially likely with regard to the demand of developing countries—African countries to be precise. Their demand has some characteristics in common with that of the population of 'New South Africa'. An industrial system might also be designed to choose to invest in market gaps untouched by big industrialized countries.

In the telecommunications sector, for instance, telephone equipment is in very short supply among African populations (Kaplan, 1990). Their needs and purchasing power scarcely correspond with the models of big international firms. There would thus be very promising work in artefact design, mass production and distribution networks. Yet, to be worthwhile, items should be manufactured in anticipation of resulting markets in Africa as a whole. Rather than intermediary technologies, as these are obviously very sophisticated, we are talking about a median position where technological creation is considered in terms of the demand. South Africa is moving its capacity down from a very fundamental 'uphill' position where it excels, to bring it closer to the preoccupations of the population (Erwin, 1992). For all that, it seems vital to the country's powers of creation and even technology transfer to maintain the scientific resources.[26] With constant inputs from an active and partially finalized science, technology transfer is what will enable the RSA to immediately set about gaining successive footholds in every African market, from the south through to the north.

## Conclusion: Long-term Prospects

The earlier sections emphasize the actors' work and the radical changes incurred by it. While leaving its historical authenticity, singularity and specificity apart, a broader understanding of it can be gained by reinscribing it into the long-term movements that it extends and expresses. This way, we can grasp a deeper meaning of contemporary phenomena without impairing their uniqueness.

The paradigm notion appears very useful for understanding current developments from an historical viewpoint, associating S&T with society and the economy. Without causal determinism, it takes regularity, conformity, equivalence and interdependency into account along with sociotechnical changes, and enables an account of the way current events are interrelated. The technological paradigm is a sum of all the equipment, procedures, know-how, training methods, industrial organizations and work management, which together coordinate production and innovation activities.[27]

The paradigm constitutes a material, organizational and institutional cognitive framework within which action is deployed. But it is temporary: paradigmatic revolution occurs when the existing paradigm proves incapable of responding to a situation, at which point a new framework is then required. The techno-economic paradigm is an extension of the concept, superimposed on economic development cycles.[28] Generally speaking, the twentieth century can thus be seen as a succession of paradigmatic phases: industrialization with heavy infrastructure, followed by *Fordism* and mass production and, finally, the advent of information and communication. Each sequence has its corresponding generic technologies (e.g., electricity, the automobile and computers respectively), working methods and individual levels of qualification. These cycles can be applied to the history of South African industrial development. During the first-half of the century, a mining paradigm prevailed with a whole sophisticated organization to exploit cheap immigrant labour, which chiefly enabled technical innovation to be delayed in various sectors. The period opened with the decision to exclude Blacks from skilled labour and the building of a single national state established under the aegis of the British crown and integrated into its exchange channels. The subsequent sequence of 'Racial Fordism'[29] corresponds to the advent of the Republic, the arrival of apartheid, authorizing of an exclusively 'White' mass market, the oligopolistic structuring of the

South African economy, its industrial diversification with recourse to varied manufacturing techniques, etc. The present-day, socio-technical changes could correspond to a paradigmatic revolution where the internationalization of the economy, the highly science-intensive technologies, the importance of qualifications and industrial flexibility could no longer fit in with the alignment of socio-professional and cultural relations upon racial divisions. This is a simple hypothesis and the temporal correlation definitely deserves in-depth observation and detailing. Yet, it opens up a line of explanation which affords a fuller understanding of contemporary phenomena in South Africa. With it, we can reconstitute the sequences of a basic evolution with the mutual effects of the events. Beyond a univocal logic of successive phases of capitalist development (Morris, 1991), however, it explains the socio-economic transformations through technical and social convergences, the most accomplished combinations of which scan the course of the country's history.

S&T in South Africa really does appear to be a major element in the broadened social reconstruction underway in this country. It is an entity sometimes mobilized by the actors and sometimes itself producer of society, though definitely never disconnected from the ongoing changes. South Africa presents a totally unique situation. Nonetheless, the analysis presented here could enable one to look at it alongside many other changing countries where dominating secular relationships are in play under conditions of extreme tension. In this sense, the social study of S&T takes its place in a 'comparative sociology of the transformations',[30] renewing development approaches for the better.

## Notes

1. This text was written prior to the change of government in South Africa and Mr Mandela's administration's takeover; as such, the new policy may have begun resolving some of the problems presented here. Having said that, the basic S&T issues at stake in the social recomposition as stated here remain as relevant in the current context of this country. A slightly different version of this text in French has been published under the title, 'Science et Technique en Afrique du Sud'. *Afrique Contemporaine*, 172 (October–December), 1994, 186–99.
2. The 'L'Afrique du Sud en Transition' conference was held in Paris in January 1993. The proceedings were published in 'Les cahiers du DEFAP', March 1993.
3. The new sociology of science has opened up an avenue of analysis in terms of associations between entities and heterogeneous actors which create 'worlds' (see Callon and Latour, 1985; Callon, 1990).
4. Two constructivist approaches can be distinguished in the sociology of S&T: the first considers that determinations between science, technology and society are symmetrical, neither having pre-eminence over the other in building worlds (cf. the authors cited in note 3); the second approach gives priority to the human social actors who are building structures that reflects and satisfy their pre-existing group interests (cf. in particular, Pinch and Bijker, 1987). Both approaches nonetheless have the same basic characteristic, that is,

showing the interdependence between social content and the content of S&T; they contest the classic epistemological vision completely isolating these contents, attributing a neutrality to scientific activity and to those doing it, as Nadine Gordimer's opening quotation marvellously illustrates.

5. Quantitative data on the size of its resources and facilities or its production figures, e.g., publications or patents. For a discussion on the scope and relevance of these indicators see Arvanitis and Gaillard (1992); see also Chatelin and Arvanitis (1992).
6. On styles of science, see Botelho (1995).
7. Figures supplied by the Foundation for Research Development (1991).
8. Take the telling example of the nuclear debate prior to the recent change of government. Before announcing that the RSA had for some time been in possession of the atomic weapon, F.W. de Klerk chose to dramatize the fact by first convening a surprise session of the three chambers with a view to informing them. There could not have been a better way to underscore the public and socio-political nature of the ongoing techno-scientific debate. It was also a shrewd way of laying out the three points of the 'framework of autonomy' programme: showing, through an a posteriori openness, that the political powers were no longer playing the role of the sorcerer's apprentice and thus reducing the 'Armageddon syndrome' affecting South Africa; nipping likely attacks on a system with a marked military calling in the bud, purging it of its most hotly debated elements; finally, ensuring these paragons of power and sovereignty did not fall into the hands of a state whose behaviour might (at that time) have been considered dubious.
9. See in particular Coll (1992).
10. On socio-technical hybridization, see Latour (1991).
11. On the science—technology—market networks, see Boyer et al. (1991).
12. Figures supplied by the Foundation for Research Development (1991).
13. Ibid.
14. Although it is impossible to describe all these initiatives, many of which were localized and spontaneous, some can be mentioned. First, the statutory councils (especially the Council of Scientific and Industrial Research [CSIR] and Human Sciences Research Council [HSRC]) have undertaken extensive restructuring since the mid- or late eighties. Second, at the beginning of the nineties, universities (Cape Town, Durban) have organized major meetings with the participation of foreign specialists or institutions such as the International Development Research Centre (IDRC) to discuss the S&T issues in the reconstruction process. At the same time, the then new Policy and Assessment Centre of the Foundation for Research Development (FRD) carried out a comparative and critical analysis of the South African research system with those of certain OECD countries. Among others, see Coll (1992); Foundation for Research Development (1991).
15. The mission wrote its 'Science and Technology Policy for a Democratic South Africa' report under the supervision of James Mullin.
16. The notions of 'symbolic capital' and 'field' have obviously been borrowed from Bourdieu; for an introduction to them see Bourdieu (1980).
17. In the sociology of science, this is where we see all the difference between two approaches: first, the institution approach analyses the relationships between groups or individuals acting in the scientific sphere, yet refrains from exploring the social content of the science itself (see Merton, 1973); after the pioneering work of the sociology of knowledge or the history of science (see Needham, 1956; Kuhn, 1962), the second approach enters the 'hard core' of scientific activity to discover the social factors at work there under various forms (see, among others, Bloor, 1976).
18. An expression by Polanyis, quoted in the report prepared by James Mullin (see footnote 15).
19. A metaphorical use of the title of J.M. Coetzee's famous 1981 novel, *Waiting for the Barbarians*, which describes the ignorance and fear in the face of approaching otherness and interactions with it.

20. On the problematization and the performative as much as resolvent translation operations, see Callon (1986).
21. See the report prepared by James Mullin (refer footnote 15); and for further details on the South African nuclear programme, its international implications and associations, see Lory (1990).
22. Beyond the distinctive features of the South African situation, the question of demand, accounting for and, therefore, representing it, is at the heart of the innovation process; see Meyer (1992).
23. See Bird (1992). The notion of a 'labour-based approach' with technological development being compatible to the employment of an abundant work force, is coming mainly from these actors; on this approach see McCutcheon et al. (1992).
24. On the dynamics of regional integration and its implications, see Maasdorp (1992).
25. For a detailed description of the terms of the debate and a synthetic approach, see Freund (1992) and Kaplan (1991).
26. The existence of a research-specific capacity is vital for absorbing the fruits of research carried out in other countries and adapted to local conditions (see Gaillard, 1991). Conceiving an applied research and banking solely on it at the expense of basic research completely sterilizes a national science system (see Arvanitis, 1990).
27. Evolutionary economists have borrowed the paradigm concept from the science historian Thomas Kuhn. The prime example is Dosi (1982).
28. Kondratieff's economic cycles have been tied in with major technical innovations by Schumpeter (1939) and extended to a globalizing socio-economic approach by Freeman and Perez (1988).
29. See Gelb (1991).
30. On the 'comparative sociology of the transformations' see Schlemmer and Waast (1992).

## References

**Arvanitis, R.** (1990). 'De la recherche au développement, les politiques et pratiques professionelles de la recherche au Vénézuela'. Ph.D. Thesis. Paris: Université Paris VII.

**Arvanitis, R.** and **J. Gaillard** (eds.) (1992). *Science Indicators for Developing Countries*. Paris: ORSTOM.

**Bird, A.** (1992). 'Research from Inside Mass Organisation: COSATU-NUMSA', in Coll (ed.). *Critical Perspectives on Southern Africa, Research and Social Transformation, Transformation*, 18–19 (Special Issue).

**Bloor, D.** (1976). *Knowledge and Social Imagery*. London: Routledge and Kegan Paul.

**Botelho, A.** (1995). 'La construction du style scientifique', in R. Waast (ed.). *La construction des communautés scientifiques*. Mimeo. Paris: ORSTOM.

**Bourdieu, P.** (1980). *Le sens pratique*. Paris: Editions de Minuit.

**Boyer, R.**, **B. Chavance** and **O. Godard** (1991). *Les Figures de l'irreversibilité en économie*. Paris: Editions de'lEHESS.

**Callon, M.** (1986). 'Elements pour une sociologie de la traduction; la domestication des coquilles St Jacques et des marins pêcheurs dans la baie de St Brieuc'. *l'Année Sociologique*, 36.

———. (ed). (1990). *La science telle qu'elle se fait*. Paris: La Decouverte.

**Callon, M.** and **B. Latour** (eds.) (1985). *Les scientifiques et leurs alliés*. Paris: Pandore.

**Chatelin, Y.** and **R. Arvanitis** (1992). 'Representing Scientific Activity by Structural Indicators: The Case of Côte d' Ivoire—1884–1968'. *Scientometrics*, 23(1); 235–47.

**Coetzee, J.M.** (1981). *Waiting for the Barbarians*. New York: Penguin Books.

**Coll** (1992). 'Critical Perspectives on Southern Africa, Research and Social Transformation'. *Transformation*, 18–19 (Special Issue).

**Copans, J., D. Darbon** and **V. Faure** (1992). 'Civil Society Arises the Phoenix'. *Indicator South Africa*, 9(4).

**Darbon, D.** (1992). 'Afrique du Sud: logiques de destructuration et stratégies ambigües de reconstruction'. *Hérodote*, 65–66 (July–September).

**Darbon, D.** and **V. Faure** (1992). 'Les voies de la recomposition'. *Politique Africaine*, 48.

**Dosi, G.** (1982). 'Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change'. *Research Policy*, no. 11.

**Erwin, A.** (1992). 'The Research Dilemma', in 'Critical Perspectives on Southern Africa, Research and Social Transformation'. *Transformation*, 18–19 (Special Issue).

**Foundation for Research Development** (1991). *SA Science and Technology Indicators, 1990*. Pretoria: Foundation for Research Development.

**Freeman, C.** and **C. Perez** (1988). 'Structural Crises of Adjustment: Business Cycles and Investment Behaviour', in G. Dosi, Ch. Freeman, R. Nelson, G. Silverberg and L. Soete. *Technical Change and Economic Theory*. London: Pinter Publishers.

**Freund, B.** (1992). 'A New Industrial Revolution? Technological Change and the Implications for South African Labour'. *Social Dynamics*, June.

**Gaillard, J.** (1989). 'La science du Tiers Monde est-elle visible?' *La Recherche*, 210 (May).

———. (1991). *Scientists in the Third World*. Lexington: Kentucky University Press.

**Gaillard, J.** and **R. Waast** (1992). 'The Uphill Emergence of Scientific Communities in Africa'. *Journal of Asian and African Studies*, 27 (1–2), 42–67.

**Gelb, S.** (ed.) (1991). *South Africa's Economic Crisis*. Claremont: David Philip Publishers.

**Harary, O.** and **D. Beaty** (1989). *A New Perspective on Public Policy and Productivity: Lessons from South Africa*. New York: Harper and Row Publishers.

**Kalpan, D.** (1990). *The Crossed Line: The South African Telecommunication Industry in Transition*. Johannesbourg: Witwatersrand University Press.

———. (1991). 'The South African Capital Goods Sector and the Economic Crisis', in S. Gelb (ed.). *South Africa's Economic Crisis*. Claremont: David Philip Publishers.

**Kuhn, T.** (1962). *The Structure of Scientific Revolutions*. Chicago: Chicago University Press.

**Latour, B.** (1991). *Nous n'avons jamais été modernes: Essai d'anthropoligie symétrique*. Paris: La Decouverte.

**Lory, G.** (ed.) (1991), 'Afrique Australe, L'Afrique du Sud, ses voisins, leur mutation'. *Autrement*, 45 (April).

**Maasdorp, G.** (1992). 'Economic Prospects for South Africa in Southern Africa'. *South Africa International*, January.

**McCutcheon et al.** (1992). 'Lessons from the Labour-based Construction of Municipal Services'. *Urban Forum*, 3(2).

**Merton, R.K.** (1973). *The Sociology of Science*. Chicago: University Press of Chicago.

**Meyer, J.B.** (1992). 'La dynamique de la demande dans l' innovation'. Ph.D. Thesis. Paris: Ecole Nationalee Supérieure des Mines de Paris.

**Morris, M.** (1991). 'State, Capital and Growth: The Political Economy of the National Question', in Gelb, S. (ed.). *South Africa's Economic Crisis*. Claremont: David Philip Publishers.

**Needham, J.** (1956). *Science and Civilization in China*. Cambridge: Cambridge University Press.

**NEPI** (1993). *National Education Policy Initiative*. Oxford: Oxford University Press.

**Pinch, T.** and **W. Bijker**. (1987). 'The Social Construction of Facts and Artifacts: Or How the Sociology of Science and Technology Might Benefit Each Other', in W. Bijker, T. Hughes and T. Pinch (eds.). *The Social Construction of Technological Systems: New Directions in the Sociology of History and Technology*. Cambridge: MIT Press.

**Pouris, A.** (1989). 'A Scientometric Assessment of Agricultural Research in South Africa'. *Scientometrics*, 17(5–6).

**Pouris, A.** (1991). 'Identifying Areas of Strength in South African Technology'. *Scientometrics*, 21(1).

**Schlemmer, B.** and **R. Waast.** (1992). 'Sociologie du développement? ou: Sociologies, en coopération?'. *L'Année sociologique*, 42, 139–65.

**Schumpeter, J.** (1939). *Business Cycle*. New York: McGraw Hill.

# Part 2

# Scientific Communities in Asia

# 8 Twists and Turns in the Formation of the Chinese Scientific Community

**Yang Anxian, Shen Aiqun, V.V. Krishna and V.P. Kharbanda**

The growth of modern scientific institutions and the formation of the Chinese scientific community have had a rather complex historical 'journey' in the course of the last four decades. Much of this complexity is centred around the relations between the state and scientific organization. Perhaps more than any other society, the political context has severely conditioned both the goal direction of scientific research and the technological developments in China. The commanding role of politics made some critical 'experiments' in directing and shaping scientific and technological activities to serve the social and economic 'ends' set by it. In doing so, the organization of science and hence the formation of a scientific community, in its sociological sense, were subjected to some 'twists' and 'turns' in their evolution during the last four decades of Chinese modern history. The transition from the Republican era to the period of the People's Republic after 1949; the influence of the Soviet 'model'; the experiment of 'planned science and technology' in the evolution of an egalitarian society; the influence of the Great Leap Forward; the decade long impact of the Cultural Revolution; and the contemporary shifts to 'market' mechanisms and 'liberalization' have all one after the other influenced the shaping of Chinese science. This paper attempts at mapping these events insofar as they influenced the Chinese organization of the science and technological system and its scientific community.

## Institutionalization and Early Growth of Modern Science up to 1949

Although China's encounter with modern Western S&T began around the seventeenth century in a small way, it was not until the mid-nineteenth century that the Chinese were acquainted with Western mathematics and astronomy to a considerable extent by the Jesuits.[1] Unlike the Japanese Meiji era (1869–1912), when major political and economic reforms were undertaken which facilitated modern science and technical learning and private entrepreneurship with state support, the situation in China for the same period reflects a rather 'inward looking' and Sinocentric self-sufficiency under the Qing dynasty. Compared to the Chinese superiority in scientific and technical pursuits in the pre-sixteenth century era,[2] the Chinese realized their declining position in a large measure by the mid-nineteenth century, particularly during the Opium Wars (1839–1842). Apart from the monumental works of Needham, *Science and Civilisation in China: 1954–1988*, a number of important studies (see for instance Fairbank, 1948; Moore, 1966; Fairbank et al., 1973; Sivin, 1980, 1982; Einsenstadt, 1987) lend considerable support to the view that till the beginning of the nineteenth century China was not able to rapidly institutionalize and operationalize modern science due to specific social and structural factors. 'Asiatic bureaucratism', as put forward by Needham, intellectual conservatism, the civil service examination system, tighter state control, mandarin values of anti-commercialism and low esteem placed on the educated stratum as exemplified by many of the earlier mentioned studies may be said to have blocked the rapid institutionalization of modern scientific systems and higher technical education.

The situation however gradually changed after the period of the Opium Wars and with the rapid Western intrusion from the last-quarter of the nineteenth century.[3] The perceived threat to Chinese political autonomy around the 1890s led to the Tong-Zhi Restoration and the Self-Strengthening Movement when some attention was paid to the promotion of Western technology, particularly in the armaments industry and communications. Zhang Zhidong, a regional reformer, coined the theory of *zhongxue weiti xixue weiyong* ('Chinese learning for the fundamentalist principles, Western learning for the practical application'). In 1889, a small group of Chinese intellectuals, such as Liang Qichao and Kang Youwei, mobilized the young reformist emperor Guang Xu to introduce both political and economic reforms to promote innovation and the rapid institutionalization of modern technical institutions. Even though the political elites realized the benefits in promoting reforms and Western S&T, they also foresaw the threat to their own legitimacy, which prevented China from undertaking any major reforms till the onset of the Republican era (1912–1949).

The constitution of the Republic—The Republic of China—in 1912 paved the way for the transformation of the social and political climate for the initial institutionalization of modern scientific institutions and the establishment of scientific societies. The return of a small group of Chinese students from Europe, Japan and North America during this time greatly contributed to the prevailing local intellectual efforts for promoting the values of science, democracy and autonomy. These efforts led to the culmination of what is known as the May Fourth Movement (MFM)[4] during 1915 and the 1920s. The launching of a youth magazine in 1915 by Chen Duxiu, a Beijing university scholar, and the journal *New Tide* by Luo Jialur and other Beijing intellectuals heralded a debate on the merits of autonomy, democracy, critical reason and Comtian positivism. As Wang (1991: 32) observes, the MFM intellectuals portray this period as 'the cumulative achievement of the first three generations of modern Chinese intellectuals who had inaugurated the struggle for the emancipation from the imperial bureaucratic State'.

The abolition of the examination system in 1905, and the influence of the MFM in the 1920s and 1930s led to the creation of several intellectual and cultural organizations from neutral political groups, intellectuals and other sympathisers for Chinese modernization and the reception of modern S&T institutions. During this period, the most significant event was the constitution of the Science Society of China (SSC) in 1914 at Cornell University by Chinese students of natural sciences, which was later transferred to China in 1918. The SSC eventually, by the 1920s, became an important first professional body of Chinese association of scientists in modern science. Under the auspices of SSC, some scientific journals were launched, and museums and research institutions established. The most significant achievement of SSC was its radiating influence in the creation of several important first scientific societies, such as the Chinese Medical Society (1915), the Agricultural Society (1917), the Geological Society of China (1922), the Société Astronomique de Chine (1924), the Chinese Meteorological Society (1925), the Physiological Society of China (1926), the Chinese Chemical Society (1932), the Chinese Physics Society (1932), the Chinese Botanical Society (1933), the Chinese Zoological Society (1934), the Chinese Geographical Society (1934) and the Mathematical Society of China (1935). By the end of the 1930s, there were about sixty-five periodicals and journals in various scientific disciplines. In the higher education[5] sector, there were 200 institutes including universities and colleges with an enrollment of 110,000 students by the late 1940s (UNESCO, 1985).

Together with the creation of several scientific societies, the need for an apex scientific academy drew the attention of the nationalist government in the late 1920s. The government created the Academia Sinica in Nanjing in 1928 and the Peking Academy was founded in 1929. By 1940, there were about thirteen research institutions under the umbrella of Academia Sinica and nine institutions under the Peking Academy.[6] These institutions and scientific societies sustained their activities due to the individual scientific efforts of scientists, most of whom were educated in USA, Europe and Japan. Both the academies existed separately for about nineteen years, after which they were merged to form the Chinese Academy of Sciences (CAS) in 1949 with the coming of the communist regime. The centre of scientific activity in the 1920s shifted to the two academies from the SSC, which however existed until the 1960s.

In the area of social sciences, one of the powerful bodies that came up in the 1930s was the Chinese Rural Economy Research Society (CRERS), organized by Chen Hanseng, an American-trained economist. This body also included other economists such as Xue Muqiao, Qian Junrui and a Soviet-trained economist Sun Yefang, who became important personalities during the era of the People's Republic after 1949. This group published the journal *Rural China*, which later advocated the marxist economic theory and sustained activities up to the post-Mao period. Together with the CRERS, the nationalist government established China's first technocratic civil service called the National Resources Commission (NRC) in the early 1930s, after the Japanese seizure of Manchuria in 1931. The NRC was formed by leading economists, scientists and engineers with a nationalist mission to overcome Japanese aggression in terms of an economic response to formulate new industrial and economic policies. As Wang (1991: 35) notes, NRC activities were the 'beginning of the institutionalization of State–intellectual collaboration in its modern form'.

Even though the initial impetus to the institutionalization of modern science was given during the Republican era, funding for the rapid growth of scientific and technical institutions did not figure as a major state venture. The nascent stage of China's S&T infrastructure in the 1940s was not capable of aiding industrial development and promoting manufacturing activity. Chinese industries depended basically on buying readymade goods and equipment from foreign sources. Although consecutive civil wars and the Japanese aggression had awakened the political elites, corresponding encouragement for the strengthening of R&D activities did not come about till the communist regime took over the government in 1949. On the whole, S&T infrastructure was very weak in the 1940s (Luo Wei, 1984). There were altogether 700 S&T personnel who were involved in research in the 1940s (CAS, 1989).

## Growth of S&T (1949–1965): Great Leap Forward and the Influence of the Soviet Model

The foundation of the People's Republic of China in 1949 brought about radical changes in S&T organization compared to the pre-Revolutionary period. In the same year, in November, the CAS came into existence with twenty-one research institutes transferred from the Academia Sinica and the Peking Academy. CAS was the only major scientific organization representing the Chinese scientific community in the 1950s and 1960s, and all through the later years up to the present period. The main goals of CAS were to engage in basic studies and applied research activities on a planned basis, strengthen the liaison among different disciplines, promote interaction between science and application and absorb advanced scientific developments from other countries.

The communist regime gave a prominent status to CAS in this period, as it was under a ministry level body attached to the state council. In the early

1950s, it was also given the charge of science planning in coordination with economic planning. Though increasing support was given to S&T by the new regime after 1949, the process of the institutionalization and professionalization of research fields also entailed the process of politicization from this period. The importance of CAS in the Chinese scientific system in the 1960s can be seen from the fact that 18 per cent of the total scientific and technical manpower resources and 70 per cent of the total research budget of China were concentrated in CAS (Luo Wei, 1984). By 1956, another thirty-eight research institutes were established in addition to the twenty-one institutes already under CAS since 1949. By 1965, the total number of research institutes under CAS totalled 120, housing an S&T staff of over 20,000 (CAS, 1989). The scientific societies during this period also gained support from the government as their numbers increased from twelve in the pre-1949 period to thirty in 1965 under the newly set up apex body called the National Federation of Scientific Societies. With the increase in the number of societies and research institutes, the number of journals in various fields of science increased from sixty-five in the 1950s to eighty in the mid-1960s.

The CAS was governed by two representatives of the Communist Party (chairman of the state commission and Chen Boda, a theorist of the Party) and five scientists (the meteorologist, Zhu Kezhen; the physicist, Wu Youxun; the geologist, Li Siguang; the economist Tao Mengho; and the president of the Academy and a man of letters, Guo Moruo, who was also affliated to the pre-Revolutionary Academia Sinica). Many of the new institutes of the CAS were headed by leading Chinese scientists such as geologist Li Siguang (with a doctorate from Birmingham University); the physicist Yan Jici (with a doctorate from the University of Paris); and neurologist Depei (with a doctorate from London University). The twenty-one older institutes of CAS were mainly located in Shanghai, Beijing and Nanjing. Most of the new institutes, created after about the mid-1950s, were located in north-west and north-east China to transfer technology from the centres of Beijing and Shanghai. As these regions were endowed with rich mineral resources of oil, coal and ore deposits, the new institutes had the objective of promoting industrialization in these areas as well.

After the establishment of CAS, along with the development of S&T and the increasing needs of national economic reconstruction, research activities in social and economic related domains were given considerable support. By the end of the 1950s, the research system in China was organized in terms of five major sectors—though the CAS continued to dominate the scientific scene. These sectors included the CAS and its subsidiary academies; institutes of higher education with limited research activities; academies and institutes under government ministries in health, agriculture, railways, mechanical engineering, metal industry, etc.; provincial and municipality controlled research institutes; and the most important of all, the defence research institutes. The overall structure of the research system in China in the 1950s actually followed the Soviet model by distinguishing between basic and applied research, reflecting broadly the division of labour between CAS, and the industrial and ministerial sectors respectively.

As a part of the Soviet influence, an important event in this period was the launching of the first long-term Twelve-Year Plan for S&T development in 1956.[7] This was an important cornerstone in that the Plan committed considerable resources for the growth of science for development. The main objectives included rapid enhancement of S&T capacity to catch up with the advanced countries within a period of twenty years; and the Plan also prioritized the four sectors of computers, semi-conductor technology, electronics and automation, and atomic energy and jet technology. It was during this period that new institutes of CAS in these areas were established, as well as institutes related to defence, space and nuclear technology (Zhu Xuan, 1983). Together with these high technology areas, the biological sciences drew considerable attention as in the mid-1960s S&T personnel in biology made up 30 per cent of the total—ranking first amongst the natural sciences.

## Soviet Influence

Much of the research infrastructure expansion of CAS and the other four high-tech sectors as noted earlier were in fact an integral part of the planned economic efforts under the influence of the Soviet model in the 1950s. By the time Prime Minister Zhou Enlai announced the Second Five-Year Plan in 1958, there already was a massive Soviet transfer of technology to China including the organization and management of S&T. As the data contained in the study of Wang (1991) shows, between 1950 and 1960 Soviets delivered US $3 billion worth of industrial equipment and machinery, and assisted China in executing 130 projects of factories for tractors, trucks, machine tools and general equipment. During the same period, about 11,000 Soviet and East European technical experts were employed in China to train, organize and administer collaborative industrial projects in communication, transportation, health, education and scientific research in crucial fields of high technology. Thousands of Chinese students were sent to the Soviet Union for training during this period. Even though Soviet assistance was abruptly withdrawn in 1960, the necessary initial industrial and technological infrastructure was already laid by this time in China due to the Sino-Soviet collaboration.[8]

In the domain of scientific research, though China began with S&T planning in 1949, much of the scientific research organization, including CAS, was 'mirrored' along the Soviet model of planning in science. Soviet planning concepts in science, and Soviet scientific theories and practices were transposed in the Chinese context. Thus, there was a massive translation of Soviet scientific literature. The journals circulating in the Chinese academies and institutes were mostly Russian, and Western literature had a restrictive screening before coming in. As Wang (1991: 49) observes, 'the ideology-based confidence and dependence on Soviet science some times distorted the internal criteria of [the] Chinese scientific community'. The official ideological stream denounced Western scientific theories, such as Einstein's theory of relativity. In the mid-1950s, the Lysenko School of Genetics was introduced from the Soviet Union, though it contradicted the established Western convictions of Chinese biologists. Further, Soviet theories and practices in the areas of cell research and physiology were also introduced into Chinese biological circles. The Soviet influence in fact went beyond science planning and into the domain of cognitive regulation of science. This led to conflicts over research autonomy between the CAS and the Party, but the 'space' for professional autonomy had already begun to shrink substantially by the late 1950s.

## Great Leap Forward (GLF)

During the period 1949–1965, whilst the Soviet influence represents a first major 'swing' to the pre-1949 status of Chinese scientific organization, the GLF (1958–1960) and its impact on science may be taken as the first major 'twist' in the organization of Chinese science. The overemphasis on heavy industry, and the expansion of applied and development research for the development of industries, both executed under Soviet influence, led to the neglect of the agriculture sector by the commencement of the Second Five-Year Plan in 1958. The slower growth of agriculture was already more than apparent. As is well-known, Mao mobilized the Party and hence the government to introduce the strategy of the GLF, which became an official development policy with strong implications for the community research system. The idea of the GLF was to accelerate the growth of agriculture as well as industrial development through the dualist use of S&T, which was officially labelled as 'Walking on Two Legs'. Capital-intensive, large- to small-scale production units, labour-intensive and backward units—all were to be simultaneously developed under this strategy. In sensitizing the scientific community, the Party ideology sought to transform the intellectuals both as 'reds' and 'experts'. All forms of protests were put down under the slogan 'politics in the command'. Under the dual strategy of 'thought reforms' and all-round development, a substantial percentage of the scientific community from the cities was sent to rural areas to assist the 'mass innovation movement' during the GLF. For instance, at the Institute of Plant Physiology at Shanghai, laboratory work was stopped for three years as scientists were sent to agricultural communities to solve their day-to-day problems. Practice was deemed as the major source of knowledge. Under the GLF movement, great importance was given to the 'wisdom of the masses', which led to the establishment of many new research institutions at the level of communities and enterprises with inadequate research facilities. In the research institutes, including those under the CAS, the criteria of evaluation for recruitment and research finalization were diluted, which led to considerable setbacks later on. There was a massive re-organization of the scientific and industrial structures to bring in new modes of experiments to bridge the gap between mental and manual labour, though with little success. By the early 1960s, the new strategy of GLF was realized as a failure, as the results fell too short of expectations. Correspondingly, the mobilization of S&T personnel to augment the GLF's objectives was given up and policies were directed towards restoring the situation. In all, the Chinese government's over-anxiety for success had imposed unhealthy impacts on the development of S&T in China. The erroneous objectives of research programmes and over-estimated dramatic results disrupted the normal order of scientific research activities.

While the Soviet influence and the GLF period inflicted major 'twists and turns' for the 'flagship' of Chinese science—the CAS—the major beneficiaries of the system were the institutes and projects, both within and outside the CAS, dealing with high technology and defence related research work. Between 1956 and the early 1960s, new institutes for semi-conductor electronics, computer technology and automation, and the Atomic Energy Commission were created and established under the CAS. The 'CAS 581 Group' was formed in the late 1950s for the promotion of satellite R&D. The Institute of Modern Physics of the CAS was transformed into a separate institute of atomic energy, which was headed by the Chinese rocket expert Qian Xuesen and the atomic physicist Qian Sanqiang. Given its military significance, a large proportion of the leading scientists of the CAS in the 1960s were transferred to the defence sector. About 45 per cent of the S&T personnel of the CAS's science division on new technologies in 1960 were engaged in defence work. Even though much of the civilian and agriculture related research experienced considerable setbacks during this period, high technology and defence related research continued to command high priority, particularly after the Soviet withdrawal of support in 1960. Overwhelming support given to these fields resulted in visible results in some of the high technology areas and science. By the mid-1960s, China had exploded its first nuclear bomb and a second one within the next year. In 1965, China developed its second generation computer indigenously, compared to the first one with Soviet aid in 1958. The R&D work on satellite technology undertaken in the 1960s enabled China to later master the technology of launching satellites.

## Short Consolation: 1962–1965

The setback to scientific organization and to the scientific community imposed by the GLF and the sudden withdrawal of Soviet aid and expertise by the early 1960s, shattered Mao's prestige to a considerable extent. There were visible gains in the high technology and defence related areas of S&T, but the 'alienation' of the scientific community under the spell of politically sponsored drives became quite apparent. From 1961 to 1963, Sun Yefang, a former member of the CRERS and director of the Economics Research Institute of the CAS since 1957, came out with a series of articles on market forces in the economy. Yefang was further joined by other scholars in advocating the notions of autonomy, incentives and profits in various economic journals. In the early 1960s, CAS proposed 'Fourteen Points Concerning the Present Work of Research Institutes of Natural Sciences' which demanded the withdrawal of political intervention in science agencies and also put forward the demand for autonomy in science organization. The emergence of new political leaders such as Liu Shaoqi, Zhou Enlai as premier and Deng Xiaoping as secretary-general of the Chinese Communist Party (CCP) at the centre sensed the growing discontentment among the leading scientists in the early 1960s, and were willing to negotiate with the intellectuals to draw greater support for general economic and social development planning. This political group eventually called for a separation of politics and profession, and also called for the diluting of directives on transforming the 'red' and 'expert'. The CAS proposal was endorsed by the Party, and Premier Zhou Enlai committed support to the scientific community at the famous Guangzhou Conference of S&T in 1962.

This brief period of consolation to the Chinese scientific community was however short lived. Mao Zedong's view did not align with Liu Shaoqui, Deng Xiaoping and Zhou Enlai's support to the reforms in the science system. To counter the Guangzhou Conference and the Fourteen Point Plan of CAS, Mao put forward the slogan of 'never forget class struggle' at the Tenth Plenum of the Eighth CCP Central Committee in September–October 1962, paving the way to abort the short period of reform. Eventually the Party faction led by Mao mobilized the Partv to launch the Charter of Cultural Revolution by the mid-1960s.

## Yet Another Twist (1966–1976): The Impact of the Cultural Revolution

The resurgence of Maoist factions within the Party, particularly the 'Gang of Four', initiated the drive for the Cultural Revolution (CR) from August 1966 with a Sixteen Point Charter.[9] Article 11 of the Charter sought to vehemently counter the liberal view and stated that 'we must criticize bourgeois reactionary academic authorities, including philosophy, history, political economy, education, literature, natural sciences etc.'.[10] Following the Twelfth Plenum of the Eighth CCP Central Committee in October 1968, the Party issued the directive that the proletariat must exercise all-round dictatorship over the superstructure, including all spheres of culture. Science was interpreted to belong to the superstructure in contrast to the GLF period when science (as knowledge) was interpreted to emanate from the field and masses at the practice level. As Wang (1991: 67) summarizes:

> . . . the polemics of the Cultural Revolution not only put science into the category of the superstructure but regarded the existing system as a producer of successors to the bourgeoisie, thus increasing the gap between intellectual and physical work, between workers and peasants, between city and countryside. Based on egalitarian considerations, the above-mentioned three distinctions were to be reduced; class struggle had to be practiced on all fronts and proletarian leadership be restored in all cultural fields.
>
> Consequently, 'revolutionary committees'—triple alliances of the military, workers and revolutionary cadres—moved into the research institutes and industrial enterprises to exercise their dictatorship over S&T personnel and carry out management work. These 'revolutionary committees' could hardly be considered as genuine 'proletarian' however, since the military played a strongly dominant role in the new organisation.

The then existing S&T organization in the mid-1960s was dismantled under the political directives of bringing in the ideological 'philosophy' of the CR, which in fact was a 'chaos' of a higher order. Under the re-organization programme, a predominant section of the scientific community was asked to move to rural areas into factories, agricultural farms and small community enterprises dealing with small-scale production for re-education through manual work, as the drive for 'thought transformation' of 'reds' and 'experts' resurfaced with greater vigour. Cities, such as Shanghai, where scientific activities were concentrated were the most affected during this period. Han Zheyi, former deputy mayor of Shanghai municipality, narrates the damage to the region's science system in one of our interviews:[11]

> The CR caused great damage to Shanghai's S&T institutions. Their people [referring to the Gang of Four] usurped the leadership over the S&T community in Shanghai, dissolved the former Shanghai municipal commission for S&T, smashed the former municipal association for

> S&T and abolished the South China branch of the CAS. Among the 144 meteorological offices or stations, 120 were abolished. About 40 per cent of the research institutions subordinated to various enterprises were dissolved.
>
> Under the disguise of an 'open-door' [policy], two-thirds of the research people were forced out of their institutes, which turned the institutes into 'hodgepodges' that resembled neither factories nor popularization stations or any other bodies they stated to transform. Many famous scientists were forced out of work for a decade.

Even though the entire spectrum of the S&T system was subjected to the drive of the CR, the CAS, which represented the mainstream Chinese scientific community, was the major victim of the CR. In 1967, the CAS budget was cut to the extent of 84 per cent of the 1965 level, and further reduced by 1976 (CAS, 1989). CAS also lost more than 60 per cent of its major research institutes, and by 1976 there were only thirty-six of them, which were directly linked to defence and military technologies (Yan Jici, 1988). Nearly half the CAS institutes with personnel, equipment and budgets were transferred to the National Defence Science and Technology Commission to be handled by the military authorities, local provinces and industries. Initially the aim was to protect some of the scientific base, but as the CR intensified during the decade a large number of these transferred scientists were not spared from being shunted into factories and farms. During the CR, basic research activities virtually ceased to exit, until about 1973 when a vigorous campaign was again launched to denounce Western science, particularly Einstein's theory, theoretical physics and Western-oriented biological sciences as in the GLF period by the Gang of Four. As Tan Aoqing, an academician of CAS and president of Jilian University, comments,

> the CR has severely damaged the Chinese S&T development and ruthlessly suppressed a great number of S&T personnel. The Gang of Four fabricated 'political earthquakes' one after another at S&T and education related departments and organisations with the basic theoretical research and teaching as the epicentre.

Another personal interview, with Han Zheyi (former deputy mayor of Shanghai municipality), made direct reference to the damage of basic sciences in Shanghai city. As Han Zheyi narrated,

> Basic theoretical research saw no credits but crimes. Famous scientists and old professors who were engaged in basic theoretical research were repudiated and many programmes were cut off. The basic research

> activities set up at the famous Shanghai Biochemical Institute were dismantled. Some of them were close to the then international level. As a result, the already existing gap was widened.

The period around 1973 however witnessed receding attacks on basic research as Zhou Enlai and Deng Xiaoping were able to mobilize the political faction of Mao; and more importantly the Nobel laureate Cheng-Ning Yang (of Chinese origin), from America visiting China, held several meetings with Mao during 1971 and 1973. The social sciences institutes of the CAS were delinked from it and placed under the propaganda division of the central committee of the CCP.

Higher technical education was another important sector which was disrupted by the CR. The number of universities was drastically reduced and China lost a whole generation of educated personnel during the decade of the CR. It is estimated that 1 million university graduates and about 20,000 postgraduates were lost during that decade. More than 300 journals were discontinued and the social organization of the scientific community, whatever existed, such as publications, scientific conferences and international contacts of the scientific community, virtually came to a standstill. Only sporadic appearances of scientific publications were witnessed during this period as the scientists perceived personal danger to their activities. The apex body of scientific associations, which had fifty-three national societies and 1,000 local ones in the provinces, municipalities and autonomous regions, was abolished. Even the State Science and Technology Commission which coordinated the scientific system was abolished and replaced by a body which was placed under the control of the Party. In the domain of agriculture sciences, the Chinese Academy of Agricultural Sciences was totally disarmed. Two of the interviews conducted with an agricultural scientist and a former minister reveal the damage done to this field of science.

> Our Chinese Academy of Agricultural Sciences was affected deeply, both internally and externally. Some research institutions were abolished and some research people were forced to change their careers. The saddest thing is that more than 200,000 species collected and accumulated during the period of the agricultural cooperation movement were lost and some unique data damaged (*Jin Shanbao, academician, CAS and president, the Chinese Academy of Agricultural Sciences*).

> The Gang of Four has caused great damage to the S&T activities in the field of agriculture. Many research institutions were either paralyzed or made to collapse. In Liaoning province, they pursued the policy of merging the academies with institutes and more than two dozen research institutes subordinated to various sectors such as agriculture, forestry,

animal husbandry, farming machinery and water resources were merged into colleges. Xiong Yue Agriculture Institute is one of the research bases which enjoyed abundant data on apples in the country. After the merger, almost tens of thousands of hybrid fruit trees were felled down and the relevant scientific data burned to ashes. Many species, resources, books, data and files were destroyed; tens of thousands of improved rice seeds were destroyed (*He Kang, the former minister of agriculture and vice-chairman of the China National Association for S&T*).

The advanced technological practices which were linked to the industrial development of the regions met the same fate as the other advanced sciences referred to earlier. Comments made by Ye Zhiqiang, the former deputy minister of metallurgy, in a personal interview, testifies to this effect.

The Gang of Four muddled people's minds, which made cadres, technicians and workers dare not talk about, study or even think about technological matters. As a result, people became strange to the technology, ill informed and poor in management. Some important technological areas, which had once reached the international advanced level, lagged behind by the end of the 1970s. The narrowed gap once again widened. For example, China started experiments on oxygen blasting furnaces and continuous ingot casting techniques almost at the same time as Japan started the same experiment. However, by 1978 Japan had transformed all its open hearth furnaces into revolving furnaces and continuous ingot casting was also widely applied. In comparison, China had not started to popularize the same technology. Computer-based steel making technology was introduced in China as early as the mid-1960s. It was then criticized as 'servility to things foreign'. Foreign experts were sent back home with the installation of the facilities unfinished. As a result, money was spent without the return from the technology.

Whilst the 'great' experiment of the CR caused enormous disturbance to the Chinese scientific organization as a whole, the political leadership guarded the high technology and military related research organization from major upheavals. Even though a large segment of scientific personnel in these areas worked under tremendous pressure and military directives, the projects in electronics, lasers, semi-conductors, advanced computer technology, and nuclear and space programmes continued to draw considerable financial and political support. For example, China was able to launch several satellites between 1970 and 1976. One of the reasons for this support given to sophisticated S&T areas was that these areas were of great national prestige and symbols of the international standing of Chinese science, both to the Maoist factions and the other leadership who expressed dissent over the impact of the CR on civilian R&D and the dismantling of the CAS.

## The Period of Restoration (1976–1980)

The disruptive drive of the CR on the Chinese scientific structure however began to recede towards the mid-1970s after the fall of the military commander, Marshall Lin Biao, in 1971. A new 'turn' thus began after this event. The moderate line of political leadership, such as Deng Xiaoping, Zhou Enlai, Chen Yen and others, who enjoyed the confidence of the scientific community and who had all along been posing resistance to the Gang of Four, were able to consolidate their position by the mid-1970s. From 1975, Mao's deteriorating health and his grandiose plans of the CR were vehemently questioned within the Party by Deng and his associates.[12] The disastrous consequences of the CR for S&T and economic development disabled the Maoist faction to further counter the rising tide of discontentment. During mid-1976, a clear division within the CCP, between the Maoist faction led by the Gang of Four and Deng including his supporters, came into sharp focus resulting in the removal of Deng from office. The source of this conflict basically emanated from Deng's three policy papers circulating which aimed at the reform of science, education and industry while strengthening the Party apparatus. The other source of the conflict emanated from Premier Zhou Enlai's famous programme of 'Four Modernizations' which was put forward at the Second Plenum of the Tenth CCP Central Committee and the Fourth National People's Congress. This programme called for the comprehensive modernization of agriculture, industry, defence and S&T. Mao's ill health did not allow him to attend both these meetings, which gave Deng and his faction an upper hand but sharpened the conflict with the Gang of Four.

The death of Mao in September 1976 changed the whole political scene in China as Deng Xiaoping re-emerged as the vice premier and Hua Guofeng took over as the Party chairman and premiership as Zhou Enlai died in February 1976. The dramatic events in this period also witnessed the arrest of the Gang of Four, which virtually closed the chapter of the CR. Insofar as the scientific system was concerned, the task before the new leadership of Hua Guofeng and Deng remained how to repose new confidence among the scientific community, restore the structure and organization of the dismantled CAS and other professional bodies and, more importantly, to put the socio-economic programme of China's modernization back on the rails. Deng's own original three policy papers and Zhou Enlai's 'Four Modernizations' became the main policy instruments of the government. In 1977, the State S&T Commission was re-established and Fang Yi, former minister and supporter of Deng, was made the minister in-charge of this Commission and also the vice president of the CAS. The social sciences and philosophy departments were detached from the CCP propaganda department and formed the nucleus of the new Chinese Academy of Social Sciences (CASS).

The new leadership in 1978 convened the National Science Conference, which was the first after 1956 and in which 6,000 S&T personnel and administrators participated. This was indeed an important national meeting which sought to arrest the whole 'twist' of the CR on the Chinese scientific system and inaugurate a new partnership for the science–state relationship for the post-1980 period. The main policy issues which emerged from the National Science Conference and Deng's[13] reform plan for science are as follows:

- Revising the earlier view, S&T was interpreted as a part of the productive forces and not as a part of the superstructure.
- Relative autonomy to scientists, and no demands on them to study political books and forcefully seek their participation in socio-political activities.
- Challenge of Mao's tenet of integrating mental and manual labour.
- The debatable issue of the class character of science was interpreted to suggest that scientists in bourgeois society work for the bourgeoisie and in China they work for the proletariat.
- Removal of the political apprehensions and enforcements over 'red' and 'expert', thereby easing the tension of the scientific community at large.
- Rehabilitation of most intellectuals labelled as rightists from 1957 and as 'class enemies' during the CR.

In 1979, the CAS scientific council was revamped with the creation of five academic departments in place of four. These were the physical–mathematical, chemical, biological, geological and technological sciences departments. From the beginning of 1980, postgraduate studies began in the universities and the CAS. By the early 1980s, the new leadership restored the whole spectrum of the S&T system that was dismantled and a new lease of life was infused into the professional system of the scientific community. Restoration of professional journals; restoration of professional ranks and the incentive system for the academic and research staff, including the engineering personnel; re-publication of scientific books and the popularization of science literature; and, most importantly, removal of direct political interference into the research system were initiated. This meant that the research institutes were allowed to be led by scientists and engineers, but the overall governing of them remained with the Party committees from outside the domain of the research system, thus marking a departure from the earlier periods. The restoration period entailed not only re-building the dismantled S&T organization but also building new infrastructure in some of the crucial areas of S&T for a new vision of China in the 1980s and beyond. The debate on the new perspectives of 'market economy' and liberalization in technology acquisition which began from the late 1970s led to new changes, both for Chinese S&T and the economy in the post-1980 period. We shall look at some of these developments, including S&T infrastructure and the status of research institutions in the following sections.

## China's S&T Infrastructure in the 1980s[14]

Together with the major reforms which came in the 1980s, particularly after 1985, the efforts of the post-Mao leadership have been laid on the building of scientific and technical infrastructure for the modernization of China's industrial structure. As the reforms unfolded in the 1980s, three main government sectors, namely, the scientific agencies, the enterprises which include the industrial and production units, and the universities and colleges constituted China's strength in R&D by the early 1990s. In 1994, China's total expenditure on R&D was 22.2 billion Yuan, which showed an increase over the figure of 3.3 billion Yuan in 1979.

CAS continues to be an important organ of Chinese scientific life, which employed 10 per cent of the total full-time R&D personnel and claimed more than 15 per cent of the total S&T budget in the 1980s. The academy, by the early 1990s, had 123 research institutions under it. Table 8.1 shows the 'ups' and 'downs' of the CAS over the last four decades. As Kuhner (1984) observes, the academy's growth can be roughly classified into three stages with the corresponding group of research institutes. The first stage consists of institutes which came up from 1949 to the middle of the 1950s. These institutes covered almost all the main disciplines in the chemical, biological and physical sciences which undertook much of the basic research in China. In the second stage after 1955, the Twelve-Year Plan led to the establishment of institutes in high technology and military-oriented research. These institutes were in the fields of computers, semi-conductors, electronics, optics, atomic energy, etc. The third group of institutes came up after the CR. These were mainly located in the rural areas to develop the industrial base of these regions and transfer the technologies from the city-based research institutions.

Scientific organizations under CAS, CASS, and the various commissions and departments under the ministries constitute China's main R&D segment, as they accounted for 55 per cent of the total national expenditure in 1987 and 50 per cent of the total S&T human resources. The government data in 1987 showed 4,690 R&D departments employing 231,000 S&T

TABLE 8.1
Growth of Chinese Academy of Sciences, 1949–91

| *Year* | *Institutes* | *Total Staff* | *S&T Personnel* |
|---|---|---|---|
| 1949 | 21 | 575 | 316 |
| 1956 | 58 | 14209 | 5281 |
| 1965 | 120 | 60258 | 21937 |
| 1975 | 36 | 48716 | 17054 |
| 1978 | 72 | 78755 | 30894 |
| 1981 | 113 | 76644 | 32975 |
| 1991 | 123 | 84909 | 59800 |

personnel[15] in this sector when the first national surveys were conducted. While the enterprises and the industrial sector accounted for 29 per cent, the university and colleges accounted for 16 per cent of the total research expenditure. The second important sector of government in R&D is the Chinese universities and colleges. Even though this sector did not play a significant part in the national research system in the past, the importance of this sector has grown suddenly from the beginning of the 1980s when the postgraduate courses began after the CR era. In 1982, the enrollment to postgraduation in science grew to 21,184 (per year), of which 20,910 were for Master's degrees and 374 for doctorates (Huang Shiqi, 1984). A survey of higher education, conducted in 1987, reveals that the R&D activities of higher education in the science sector are concentrated mainly in the eighty-six universities and colleges. The third major government sector is the large and medium enterprises or industries, which are about 9,000 in number employing about 700,000 scientific and technical personnel. After the 1980 reforms in S&T, a new segment of R&D and production enterprises, known as collective ownership and individual ownership enterprises, have taken roots in China. According to a survey, there were about 1,500 enterprises of these types in the late 1980s.

According to the statistics, personnel engaged in activities related to S&T has shown an increase from 5.95 million in 1979 to a figure of 26.58 million in 1995. Out of this, 15.29 million are scientists and engineers. It may, however, be pointed out that while the number of scientists and technical personnel engaged in R&D work is small in actual terms, the number of 'full-time equivalent' solely carrying out R&D work per se is much smaller than generally assumed by the available statistics.[16] While the data shows a large size in absolute terms, it however conceals the low level of expertise and education; and the figures available are inflated due to the inclusion of the public health and education sectors.

### Scientific Societies and Associations

In the beginning of 1980, the dismantled apex body of scientific associations was again revived under the name China Association for Science and Technology (CAST). In 1981, this body had fifty-one science centres and clubs all over the country, and through the decade it has witnessed substantial expansion of its activities. From the 1980s, CAST has been instrumental in publishing 1,500 popular science publications and 150 popular science magazines with a circulation of 20 million copies. CAST now has under its umbrella 146 national professional societies in various scientific disciplines (as separate research associations) with coordinating links with the inter-regional and trans-regional bodies of science associations. CAST has an affiliation of ninety-five academic bodies. Of the 146 societies, there are thirty-five natural science societies, fifty-eight engineering societies, twelve agriculture societies, nineteen medical societies and twenty-two interdisciplinary and popular science-oriented societies with an estimated membership of 1.71 million people. Under the auspices of CAST, 300 professional journals are edited by various national level professional societies (CAST, 1988). The activities of CAST are, however, not confined to the cities but its influence is radiated in the villages as well (ibid.). In parallel with China's administrative divisions, CAST maintains a corresponding organizational structure at different levels of provinces, prefectures and counties. As CAST is under the CCP, it reflects the views of science derived from the Party's ideology and the body has been subjected to shifts in its orientation from time to time (Kharbanda and Qureshi, 1987).

## New Turn (1980–1992): Major Reforms in S&T, the Scientific Community and its Economic Role

The decade of the 1980s, better known as China's post-Mao era, witnessed a new bout of economic reforms advocating the importance of the market mechanism and decentralization in the economy, thereby further loosening political control but not the 'ideology'. Whilst the scientific community, CAS for example, gained more autonomy in decision making and research direction, the liberal economists and social scientists were able to influence the political system more than any other period in Chinese history since 1949. The creation of the Economic, Technological and Social Development Research Centre (ETSRC) by the merger of four research centres led by liberal economists played an important part in advocating the reform programme. A new alignment of intellectuals, bureaucrats and the political leadership in the reform programme after the creation of new 'think-tanks' by the Party in the 1980s eased the tensions, paving the way for negotiation rather than the 'political enforcement' of the CR era.

In October 1984, the government adopted a major reform document known as the 'Resolution of the Central Committee of the CCP on the Reform of the Economic Structure'. This document pointed out the problems inherent in the over-centralization of the industrial economy of China, defects in the urban economic sector, the importance of promoting scientific and technological development for generating new forces of production, and directives for market mechanisms which gave more autonomy to all enterprises and industries including those in the provincial and local regions. The thrust of the reform package divested the central government of its over-centralized managerial role and brought a shift from 'mandatory' planning to 'guidance' planning. The system of pricing, incentives in production, ownership of enterprises by individuals and groups, liberalization of the economy by allowing foreign enterprises (thereby creating a new situation of competition) and other economic reform measures were introduced in the 1980s.

In the domain of S&T, the government issued the document 'Decision on S&T System Reform' in March 1985. It promulgated that the S&T system reform should be closely linked to the realization of the modernization goals of China. This document also stressed that 'economic construction should rely on S&T and S&T development should serve economic constructions'.[17] Insofar as science is concerned, CAS took the lead in the reform and lifted the curtain for all-round science reform in China. Before we look into the main reforms which influenced the scientific research structure, let us briefly explore the decision making structure in science as it prevails in the early 1990s.

## S&T Decision Making

Decision making bodies in China can be divided into two streams, namely, administrative decision making and the S&T consultation system. In China, the top decision making body responsible for S&T policies is the National People's Congress (NPC), to which the Committee for S&T and the Committee for Systems are subordinate. Important acts or regulations concerning S&T development are required to be reviewed and ratified by the NPC; the top administrative organization responsible for the studying and formulation of important national S&T policies is the State Commission for Science and Technology. It is responsible for providing guidance to various state commissions and ministries, the CAS, academies in agriculture and medical sciences, patent offices and S&T activities which take place at the provincial and municipal levels.

The Academic Board Meeting of the CAS is the top academic authoritative body in China. It is responsible for reviewing and voting on important academic issues relating to S&T development in China and for presenting formal proposals to the government. The Academic Board is composed of famous and renowned scientists. Social studies of S&T have now come to play an increasing role in the S&T decision making system. In addition to various 'think-tanks' at the top level linked to the government, and those which are located in the CAS and in institutes of higher education, there are researchers who undertake various policy-oriented studies and give inputs to the national decision making in S&T.

## Reform at CAS

CAS now has 123 research institutes spread over the country. In the middle of 1981, the fourth conference of the CAS scientific council was convened after 1960. Four hundred members were elected including scientists and engineers from CAS, institutes of higher education and R&D units from industrial enterprises. The new council was mandated to evaluate research and given charge of planning. Fang Yi, who was a bureaucratic figure, gave way for two natural scientists, Lu Jiaxi and Yan Dongsheng, to take charge as president and vice president respectively for the first time. The important event here was that for the first time these two scientists were elected by their peers. The crisis in the leadership of CAS was ultimately settled in the early 1980s in favour of the internal control of the academy, and thus the scientific community. The council in the early 1980s also constituted the CAS Science Foundation for funding basic research based on the criteria of peer review. The newly infused 'autonomy' of CAS was however a negotiated result, as CAS from the 1980s also took a leading part in the reform of the S&T system, which entailed defining its relevance for the industrial development and economic growth of China.

Under the guidelines set up by the government that 'S&T activities should serve economic development and economic construction should rely on S&T', CAS introduced various mechanisms in its restructuring, which are as follows:

REFORM OF THE CURRENT ALLOCATION SYSTEM: Classification management was introduced in research activities from the early 1980s. Since 1981, CAS has gradually decreased the weight of appropriations, and expanded the part that important research items and priority projects should get more funding. In 1985, 35 per cent of its total funding was allocated based on the principle of preferential treatment of priorities. Comprehensive surveys would be made at various institutes and the proportion of three kinds of studies—basic studies, social- and public interest-oriented studies, and technical development—would be worked out. Funding for technical development was decreased year by year. People in this field were supposed to seek funding from the market.

'OPEN' LABORATORY SYSTEM: Prior to 1985, CAS was plagued with low mobility of personnel, which consequently caused rapid aging of the staff, 'fossilization' of knowledge, and lack of interaction with universities and industry. This also resulted in institutional compartmentalization, overlapping of research and low utilization of research facilities. In 1984, to break up the so-called 'institute ownership', CAS established a number of new research facilities based on the principles of 'open, mobile, collaborating and serving the whole country'. CAS opened two research institutes and seventeen laboratories to scientists outside the Academy in 1985, which was increased to sixty-five laboratories and eight working stations by the early 1990s. A number of institutes with modern facilities opened their doors to researchers from the entire country.[18]

CONTRACT MANAGEMENT: From 1985, the contract system has been introduced into collaborative studies of some important S&T issues relating to the development of the national economy. In this system, responsibility is defined between the contracting parties to ensure the completion of tasks. CAS took forty-seven major projects from the 'State S&T Priority Projects Plan' during the period of the Seventh Plan by using the contract system.

ESTABLISHMENT OF SPIN-OFF COMPANIES: To solve the issues of low value, poor record of enterprises in absorbing new technology and introducing new research in the market, CAS has created a number of hi-tech spin-off companies since 1984. A number of scientists went out of their laboratories to start ventures at these spin-off companies. With S&T as back-up and the market as the orientation, an integretated entity of a research, development, production and marketing net has been formed. Some of the spin-off companies such as Legend Group, Shangahai Nisala Company and Hi-tech Electronics Company have made remarkable achievements. Many of the electronics and computer companies were established in affiliation with CAS and institutes of higher education. These companies are concentrated in the street known as 'Electronics Street' in Beijing. The other well-known companies which are in operation by now are The Great Wall Consortium, The Beijing Stone Computer Company and Syntone Company. In 1988, the turnover of these hi-tech enterprises reached 1 billion Yuan and they earned foreign exchange of more than US $10 million.[19] The achievements of these companies have established their standing in Chinese society.

ONE ACADEMY WITH TWO RUNNING MECHANISMS: In the course of the reforms, two totally different systems have been gradually formed in CAS. One is the scientific research system with activities stemming from the research itself. This segment also addresses the strategic and fundamental issues relating to social and economic development. The other is the technical development system which is concerned with the development of technological products in engineering, new products and marketing. From 1988, separate assessment standards, running mechanisms and management have been introduced to assess the activities in the two mechanisms of CAS. Practice over the last few years has shown the viability of dualism in the activities of CAS.

## Three-tier Research System of Chinese S&T

In the first-half of the 1980s, all formal R&D work, and most of the product, process and commercialization activities have been carried out in the public sector, and have been directly or indirectly funded by government. In fact, state control had been all-pervasive in allocating resources to specific projects and programmes until the reforms of 1985. After this period of reforms, one aspect of the funding system that has received major attention is the policy of reducing direct state allocations of operating funds, thereby putting the pressure on the R&D sector across the board to find alternative sources of funds through contract work, transfer fees and sale of technological know-how. For the first time a new patent law was issued in 1984, the Technology Contract Law was promulgated in 1987 and national standards in industry came in to the life of enterprises. The S&T reforms created a context in the technology markets for the transfer of technologies. The spin-off companies from the CAS scientists referred to earlier is one such important change in the creation of new technology markets. The reforms also allowed the provincial and non-central authorities to contract, purchase and provide incentives for promoting technological know-how in production. New laws for tax incentives for companies which undertake research are now in operation, both at the central and non-central levels. For example, Haidan district government in 1988 decided to implement tax exemption schemes to promote scientist–entrepreneurs. Further, the 'opening' of China to foreign enterprises after the latter part of the 1980s has also created sources for Chinese technological supply. From the mid-1980s, the scientific institutions in China have been evolved to work under a three-tier S&T strategy.

At the first tier, the resources and capabilities are mobilized directly to serve the country's economic construction; and under this tier roughly two-thirds of the country's S&T resources have been deployed. This tier includes the SPARK programme installed in 1986 for the application of S&T to rural areas and the National Key Research Project for the entire manufacturing sector. The SPARK programme has the involvement of 400,000 scientific and technical personnel. During 1986–1990, the Key Research building, natural resources, environment and healthcare, with the involvement of 100,000 scientists and technical people.

Closely related to the first tier system was the new reform policies on defence R&D, which led to the transfer of technological know-how to civilian R&D and industry. This was intended to break down the barriers between the two and also strengthen the civilian enterprises. Since the modernization drive was a costly affair, the transfer of defence know-how was also meant to reduce foreign dependence and economize the technological modernization. In the 1980s, defence factories were involved in the production and marketing of motor cycles, refrigerators and consumer electronics, while the high technology component of the defence sector continued to deal in satellites and nuclear power plants with enhanced collaboration with CAS.

At the second tier, reasonable S&T resources are devoted for the development and application of high technologies, which have recurrently during the past three decades attracted the support of the government. A new '863 Plan' programme was initiated in 1986 and another 'TORCH Plan' programme launched in 1988 for tracing and developing high technology and new technology.[20] The role of CAS in forming the high technology lobby in the launching of the '863 Plan' was considerable. Under these programmes, the seven priority areas are biology, space, information, lasers, automation, energy and new materials. The 'TORCH Plan' had a radiating impact for the proliferation of science parks or gardens, including high technology zones in China. The four major science parks are in Shanghai, Nanjing, Beijing and Wuhan. Haidan district in Beijing is the main R&D technology force as CAS and other top technical universities are located in this area. Shanghai may be said to be developing as the Chinese version of 'Silicon Valley'. Many joint ventures and 'consortia model' companies have come up in this region.

At the third tier, a short but strong contingent of the most creative scientific and technical personnel is deployed to work in basic research and frontier areas. The CAS Science Foundation, created in the early 1980s, was reconstituted as the National Natural Science Foundation in 1985 to give a boost to basic and fundamental research. As many as 100,000 scientists and engineers are involved in 20,000 basic research items, of which 3,000 are funded by the Foundation on an annual basis. Compared to the total research effort, basic research constitutes a small proportion (6.7 per cent), while the rest is applied (30.5 per cent) and development research (62 per cent).

## Institutional Incentives and Reward System

The decade of the 1980s witnessed the infusion of new confidence in the scientific community as a whole. While the elite scientists were able to regain their status and legitimacy, both in the political and societal spheres and at various levels of generality, the social situation of the research climate for neophytes and ordinary members of the community offered new opportunities and sources to realize their creative potential. Compared to the 'chaos' of the CR era, the promotion of S&T personnel in various research institutions from the 1980s is based on a professional appointment system with corresponding avenues for advancement. Explicit terms of reference and conditions for appointment are worked out for the various positions in the higher, middle and lower S&T levels of appointment. For example, in the case of natural scientists, regulations have classified four levels for researchers with corresponding qualifications and experience as shown in Table 8.2. The advancement of personnel from one level to another level is assessed by a professional committee, as is also the case with new recruits in the research institutions. Emoluments and other incentives have also been worked out according to the professional levels and positions in the institutional hierarchy. In addition to the advancement avenues within the research institutions, members of the scientific community can now compete for various science awards given by various agencies at the state, ministerial and local levels, and by CAS according to their professional contributions.

**TABLE 8.2**
**Selection Criteria for Researchers in Research Institutions**

| *Research Type* | *Selection Criteria* |
|---|---|
| Research Practitioner | Master's or Bachelor's degree in science with one year of research experience |
| Research Assistant | Doctorate or Research Practitioner with four years of research experience and capable of independent research capacity |
| Associate Research Fellow | Research Assistant with five years of research experience without a doctorate or Research Assistant with three years of experience with doctorate |
| Research Fellow | Associate Research Fellow with more than five years of research experience and recognition through publications at the international level |

The national rewarding system has been gradually standardized over the last decade. There are different types in each of the award categories. For example, the state award, which is the topmost award, has four types, viz., invention award, natural science award, S&T award and special award for popularization. The first two awards were set up by CAS. As Wang (1991: 128) observes, 'by emphasising the importance of scientists, researchers and technicians and by rewarding inventive work and talent rather than politics, the Chinese government hoped to raise the consciousness of the society as a whole'.

Since 1992, due to the major turn of events in the form of new reforms from the decade of the 1980s, the Chinese scientific and technological system has entered a new era. Reforms have brought about new opportunities and challenges to the scientific community, even though the new mechanism has not been fully developed. There are various efforts going on in the political and economic spheres which suggest that the new system is fast developing and trying to incorporate the market economy and internationalize the Chinese scientific system.

## Concluding Remarks

The part played by the political 'structures' and 'superstructures', both in institutionalizing modern S&T and in shaping its social organization, has been a dominant theme of the contemporary history of Chinese science in the post-War period. Politico-economic experimentations launched on a mass-scale during the GLF and the CR had a totalizing impact on the scientific research system, which left only a residual social space for 'natural growth' and 'autonomous' development of the scientific system. An appropriate professional climate, crucial for the formation of scientific communities at the meso and macro levels, was recurrently disrupted at different historical moments during the 1950s and the late 1970s by intervening political radicalism. Making scientists serve the needs of the countryside and factories through political means did not work out as a fundamental solution due to the divorce of S&T from production in terms of the system itself. The defence and strategic related component of S&T was, however, kept insulated from various upheavals during all these years. Under the highly centralized planning system, the government succeeded in military and heavy industries only.

But insofar as the civilian scientific research system is concerned, there were several efforts (both from the dissenting political factions and the elite community of scientists) towards consolidation and rejuvenation. But each time the concerned groups and individuals found themselves stripped of their efforts under pressure and were subjugated to the tides of 'new experiments'. Political stretching of S&T beyond the possible means had a diminishing 'elastic' impact on the potentiality of the scientific and technical structures. Despite recurring problems, it may be pointed out that the Chinese scientific system, in its various ramifications, contained small 'pockets' of an 'inner' professional core which could withstand the 'twists' inflicted upon its path. It was this critical mass (in terms of individuals and core groups) with international support that ultimately helped the rejuvenation process. Even in the midst of the CR, when S&T institutions were dismantled, this small elite (both political and scientific) interacted with international scientific circles. The Chinese-American scientists (that is, Chinese scientists settled in USA) and CAS formed a 'physics lobby' from the late 1970s (see Wang, 1991) to keep alive the 'scientific spirit'. These foreign Chinese scientists, notably Nobel Prize winners such as Cheng-Niang Yang and Cheng-Tao Li, visited China several times and are reported to have kept personal relations with Mao Zedong and Zhou Enlai from the early 1970s.[21] The fact is that even this important international scientific connection had to be routed through the higher echelons of the political system. The local critical mass which formed an important intellectual lobby in science and which interacted with international science circles particularly came from the CAS, which all through represented mainstream Chinese S&T.

Before 1980, the legitimacy of the scientific community depended solely on the benevolent orientation of the political party system. It is only from the early 1980s that the scientific community may be said to have consolidated its status and position in the sense that the legitimacy for science is drawn from sources other than the political system. The market 'locale' (internal and external), the international system of science, foreign and local enterprises and industry operating in China, and the local agricultural and socio-economic needs are the most important agencies, which are not only new sources of legitimation for the scientific community but in various ways have also created a new demand pattern for the Chinese economy and S&T. The policies of reform and the corresponding decentralization process brought in after 1980 have made possible this new scenario. In the process of opening up and reforms it was found that the divorce of S&T, referred to earlier, is the result of the factors inherent in the system itself and its running mechanism. In the present day context, the Chinese scientific community has been entrusted with the dual role of generating new knowledge as well as combining S&T with the economy through the market mechanism. Accordingly, scientific institutions in China are being evolved to achieve this dual objective. Only when S&T plays a more effective role in the national economy (which includes the agencies referred to earlier), can it win support from the government.

## Notes

**Acknowledgements:** We would like to thank the Science, Technology and Development Group of ORSTOM, Paris, and NISTADS, New Delhi, for rendering help in several ways, without which, writing this paper would not have been possible.

1. According to Needham's monumental volumes on China, it was exactly 1601—the year in which the Italian Jesuit Matteo Ricci obtained a stay permit in Peking from the Emperor. He is known to have transferred Western mathematics and astronomy, and also to have rendered help in reforming the calendar. French King Louis XIV in the seventeenth century broke the Portuguese monopoly by sending French Jesuits, who were correspondents of French academies. Some detailed discussion on Western mathematics in China during the seventeenth and nineteenth centuries can be seen in Jami (1992).

2. As Salomon and Lebeau (1993: 133) remind us, 'the three most important technical innovations of the European Renaissance—the compass, gunpowder and printing—were all Chinese inventions, and Needham's study indeed shows how far ahead of the Europeans the Chinese were at that time'.
3. There is enough evidence to suggest that while human sciences, philosophy, documentary proofs, etc., progressed, China lagged behind Western S&T until the mid-twentieth century.
4. MFM is one of the famous youth movements in China which aimed at combating feudalism and bureaucratic capitalism during this period of Chinese modern history. After the foundation of New China in 1949, 4 May was formally declared as China's Youth Day.
5. By the 1940s, some famous universities included Qinghua University established in 1911 and Beijing University.
6. The thirteen institutes under the Academia Sinica were in geology, astronomy, meteorology, social sciences, physics, chemistry, engineering, history and languages, psychology, zoology, botany, preparatory division of medical research and mathematics. The nine institutes under the Peking Academy were in physics, crystallography, atomic studies, chemistry, zoology, botany, physiology, pharmacy and history.
7. In fact, this Plan defined fifty-seven major S&T and theoretical subjects which, among other high-tech areas, included peoples' health, forestry and agriculture.
8. In 1960, the former Soviet Union unilaterally 'tore' up the cooperation agreements between China and the Soviet Union. One hundred and fifty-six planned and ongoing industrial construction projects were suspended and technical assistance that was promised to China was withdrawn. This episode caused a great setback to the modernization programme of China at that time.
9. The central committee of the CCP published *The Decision on Proletarian Cultural Revolution*, which was an authoritative document guiding the CR. Since then, science, education, media and arts communities were submerged in the 'winds' of the CR.
10. Quoted from the *Peoples Daily* (Beijing), 9 August 1966.
11. Two of the authors who are stationed in Beijing conducted a number of interviews with several scientists, engineers and party members on the impact of the CR. Most of the people interviewed were in one way or another affected by the CR in their activities. However, due to paucity of space, we furnish only a small portion of the interview data, as and where applicable. It may be pointed out that the material presented has been translated into English.
12. In 1975, when he resumed his responsibilities over the routine activities of the central committee, Deng proposed the state policy of 'Stability and Unity' and 'Rectification', especially the instruction of 'consolidating the Chinese Academy of Sciences and strengthening its leadership'.
13. In 1978, Deng made an important speech at the National Science Conference convened by the Central Committee reiterating the lines proposed by Zhou Enlai in 1963. There was some alignment of thinking between Deng and Zhou Enlai.
14. Factual and quantitative data which specifically figures in this section and elsewhere in the paper is drawn from a number of sources. Some important ones are: CAS (1991); *Xiuhua Monthly* (1985); PRC (1989); *Law and Acts Selection, PRC, 1949–1988* (1990); *Statistics for CAS for 40 years*, CAS.
15. This data includes 121,000 technicians.
16. For a detailed analysis of the manpower constraints in R&D see Zhang Li (1988). In 1990, this number was 617,100 personnel.
17. This document also called for the reform of the budget allocation system and for the enhancement of the mobility of research personnel across various R&D settings and places.
18. See Dugan et al., 1988.

19. These figures are being quoted from *CAS Journal* (1989), 'Overview of a Decade's Reform in CAS', 14(3).
20. The '863 Plan' specifically refers to 'The Outline for High Technology Research and Development Planning' prepared by the government in March 1986 to trace the latest developments in high technology in the world. It came into force in 1987. The 'TORCH Plan' was launched by the S&T Commission in July 1988 to develop high and new technology industries on the basis of high technology products developed by the S&T community, and for creating high technology spin-off enterprises.
21. It may be pointed out that this international connection in science has tremendously progressed in the 1980s. The Society of Chinese Bioscientists in America (SCBA), led by Rutgers University pharmacologist Chung Yang, is committed to advancing careers of Chinese-American scientists and then radiating the expertise and excellence to the laboratories in China. See *Science* (1993), Special issue on 'Asia Puts its Stamp on Science', 262(5132), 345–80.

## References

CAS (1989). *History of CAS*. Beijing: Contemporary China Books.

———. (1991). *Annual Report*. Beijing: CAS.

CAST (1988). *CAST—Report*. Beijing: CAST.

**Dugan, Kathleen G.**, **Su Dajun** and **Yang Ji** (eds.) (1988). *Science and Technology in China: Selections from the Bulletin of the Chinese Academy of Science*. Beijing: International Academic Publisher.

**Eisenstadt, S.N.** (ed.) (1987). *Patterns of Modernity, Volume II: Beyond the West*. London: Frances Pinter.

**Fairbank, J.K.** (1948). *The United States and China*. Cambridge, Mass: Harvard University Press.

**Fairbank, J.K.**, **O.R. Edwin** and **A.M. Craig** (1973). *East Asia: Tradition and Transformations*. Boston: Houghton Miffilin.

**Huang Shiqi** (1984). 'Higher Education in China: The Past Five Years', in R. Lalkaka and Wu Mingyu (eds.). *Managing Science Policy and Technology Acquisition: Strategies for China and a Changing World*. New York: UNFSSTD.

**Jami, Catherine** (1992). 'Western Mathematics in China, Seventeenth Century and Nineteenth Century', in P. Petitjean, C. Jami and A.M. Moulin (eds.). *Sciences and Empires: Historical Studies about Scientific Development and European Expansion*. Dodrecht, The Netherlands: Kluwer Academic Publishers.

**Kharbanda, V.P.** and **M.A. Qureshi** (1987). *Science, Technology and Economic Development in China*. New Delhi: Navrang Publishers.

**Kuhner, Hans** (1984). 'Between Autonomy and Planning: The Chinese Academy of Sciences in Transition'. *Minerva*, XXII(1), 13–43.

**Luo Wei** (1984). 'Inter-flow of Research Achievements, Knowledge and S&T Personnel', in R. Lalkaka and Wu Mingyu (eds.). *Managing Science Policy and Technology Acquisition: Strategies for China and a Changing World*. New York: UNFSSTD.

**Moore, Barrington, Jr.** (1966). *Social Origins of Dictatorship and Democracy: Lord and Peasant in the Making of the Modern World*. Cambridge, Mass: Harvard University Press.

PRC (1989). *S&T Major Events*. Beijing: S&T Press.

——— (1990). *Four Decades: China's S&T Development*. Beijing: China Statistics Press.

**Salomon, J.J.** and **A. Lebeau** (1993). *Mirages of Development: Science and Technology for the Third World*. Boulder, Co: Lynne Rienner Publishers.

**Sivin, N.** (1980). 'Science in China's Past', in Leo A. Orleans (ed.). *Science in Contemporary China*. Stanford, California: Stanford University Press.

**Sivin, N.** (1982). 'Why the Scientific Revolution Did Not Take Place in China or Did It?'. *Chinese Science*, 5 (June), 45–66.

**UNESCO** (1985). *Statistical Year Book*. Paris: UNESCO.

**Wang, Yen-Farn** (1991). *China's Science and Technology Policy: 1949–1989*. Stockholm Studies in Politics, 39. Stockholm: University of Stockholm.

**Yan Jici** (1988). 'Development of Chinese S&T in Last Three Decades'. Mimeo. Beijing: CAS.

**Zhang Li** (1988). 'An Analysis of China's R&D Manpower Input Intensity'. *Research Management*, 2.

**Zhu Xuan** (1983). 'A Probe into the Policy of New Technology Development'. Paper presented at the Beijing International Conference on Science and Technology Policy and Research Management, 4–8 October 1983. Also published in R. Lalkaka and Wu Mingyu (eds.). (1984). *Managing Science Policy and Technology Acquisition: Strategies for China and a Changing World*. New York: UNFSSTD.

# 9 A Portrait of the Scientific Community in India: Historical Growth and Contemporary Problems

**V.V. Krishna**

Establishing a Sanskrit School under Hindu pandits . . . can only be expected to load the minds of youth with grammatical niceties and metaphysical distinction of little or no practical use . . . . But as the improvement of the native population is the object of the government, it will consequently promote a more liberal and enlightened system of instruction, embracing Mathematics, Natural Philosophy, Chemistry, Anatomy, with other useful sciences, which may be accomplished with the sum proposed by employing a few gentlemen of talent and learning, educated in Europe, and providing a college furnished with necessary books, instruments and other apparatus.

*—Raja Rammohan Roy's letter to the Governor-General, 1823*

Indians are incapable of any original work in natural science . . . . If indeed it exists as yet in this variety of human race . . . so let us exercise a little discretion with our weaker brethren and not expect them to run before they can walk.

*—H.B. Medlicott, Head, Geological Survey of India, 1880*

We should endeavour to carry on the work with our own efforts, unaided by the government. I want it to be entirely under our management and control. I want it to be solely native and purely national.

*—Mahenderlal Sircar's observation during the establishment of the Indian Association of Cultivation of Science in 1876, from which the first Indian won the Nobel Prize in physics in the 1930s*

It is science alone that could solve these problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste of a rich country inhabited by starving people.

—*Jawaharlal Nehru at the Indian Science Congress, 1938*

Science in its instrumental fields of activity, has played an ever increasing part in influencing and moulding human life . . . . Industrial, agricultural and cultural advance, as well as national defence depend on it. Scientific research is, therefore, a basic and essential activity of the State and should be organised and encouraged on the widest scale.

—*Manifesto of the Congress Party for the first national government declared in 1945*

The introduction of modern S&T, its institutionalization and professionalization, resulting in the growth of the Indian scientific community, has traversed a complex terrain during the last few centuries in India. First, the struggle over the colonial science policies and economic exploitation, and later, after independence, the efforts to build scientific infrastructure to modernize and industrialize India present us with a continuing theme of challenges and struggles confronting the Indian scientific community. The opening observations made by important personalities at different periods and circumstances of Indian history only microscope the contours of this complex social, economic and political terrain. These personalities, and other actors and agencies who constituted this terrain to condition and shape the scientific and technical developments in India, and their bearings on the growth and structure of the scientific community form the main subjects of this paper.

The first section traces the growth of science during the colonial period, its impact and the Indian intellectual response to these developments. This section highlights the way in which the response from the Indian scientific intelligentsia, widely supported by the then emerging National Movement and private wealthy supporters, laid the ground for what was known as the development of the national science phase. The significance of this phase is shown to have led to the genesis of the Indian scientific community in its embryonic form.

The next section traces how the influence of national reconstruction policies through S&T, which were essentially embodied in the national science phase, governed the post-independent growth of S&T infrastructure under the leadership of Nehru. The close alliance that Nehru forged with a small elite of Indian science helped India embark on a massive programme to build institutional infrastructure in science. The statistical scenario of this growth, and the actors in S&T who formed the science–politics nexus and who were responsible for the growth of S&T in India after 1947 in certain specific directions are the main issues discussed in this section.

The third section is of a more contemporary relevance in the sense that it attempts to map and locate the Indian scientific community of the 1980s in an international context. The legacy of the national science phase in terms of the policies which governed the strategies in S&T further figure in this section. More specifically, two sub-sections here broadly deal with the 'intellectual' and 'practical' features of the Indian scientific community. Notwithstanding the centre–periphery dichotomy in the Third World science perspectives, as seen in the scientometric analysis, the former attempts to locate the Indian scientific community in its present mould of growth as a 'middle range' community. Extending this argument further into the 'practical' realm of a scientist's activity, the sub-section identifies those important factors which were responsible for the under-utilization of the R&D capacity of the Indian science community. In so doing, the strengths and weaknesses of the Indian science community are discussed with some empirical support in this section.

## Colonial to National Science[1]

Over the last two decades, historical research on science, technology and imperialism has considerably enhanced our understanding of the social processes underlying the growth of modern S&T and its institutionalization in former colonies such as India. The important contributions of Fleming (1964); Basalla (1967); MacLeod (1975, 1987); Headrick (1981); Worboys (1979); Inkster (1985); and Kumar (1986) in varying ways lend legitimacy to the concept of colonial science. This term broadly refers to the status of scientific and technological activity under colonialism in the colonies, and its subjugation to the imperial political and economic interests in the metropolis. As these earlier mentioned writings demonstrate in varying ways, the organization of science in the colonies was indeed a planned activity from the metropolis. The colonies were assigned the subordinate tasks of 'data exploration' and application of existing technical knowledge, while the theoretical synthesis took place in the metropolis. Devoid of its intellectual essence, the goal of scientific practice in the colony was not the advancement of science, though there were marginal exceptions, but the exploration of natural resources, flora and fauna to feed the intellectual and industrial 'revolutions' in the metropolis.[2]

The expansion of modern science in India progressed with the establishment of the Asiatic Society of Bengal (renamed as the Royal Asiatic Society of Bengal in 1936) by William Jones—an orientalist and a representative of the British East India Company—in 1784. The gradual spread of

British colonial hegemony over two-thirds of the Indian territory by the turn of the twentieth century witnessed the introduction of large technological projects in railways, telegraphy, canal irrigation and public works departments, together with the large-scale expansion of colonial scientific enterprises.[3]

Even though the colonial government established a large number of scientific enterprises, paving the way for the institutionalization of science, the structure of these enterprises was that of colonial science. In terms of the organizational structure, the upper berths of the hierarchy were dominated by the British technocracy. As Kumar (1983) has shown, racial discrimination in the recruitment of Indian scientific personnel was widely prevalent. P.C. Ray (1921), the doyen of Indian chemistry, could count only eighteen Indians out of 213 scientific personnel in eleven scientific enterprises in 1920.[4] For instance, the Asiatic Society of Bengal cooperated with the British Geological Society to promote Indian resource development. The data gathered and sifted from the colonies not only aided the scope of British geology, but the colonial science organizations, such as in geology, served as an important basis for colonial policies on minerals, coal mining, agriculture, transport surveys and communications (Stafford, 1990).

From the last-quarter of the nineteenth century, the need for scientific autonomy and professional recognition for Indian science was struggling to find expression as a part of the emerging Indian national consciousness. Various groups and individual scientists, widely supported by wealthy Indian landlords, a small section of British and European supporters of the Indian cause, business groups and political intelligentsia set an agenda to fight colonial science on the one hand, and to create alternative structures to professionalize and integrate modern S&T within the framework of the Indian National Movement on the other hand.[5] As the size and social consciousness of Indian scientists grew, the division with colonial science paving the way for the development of national science gained momentum with practical efforts.

The first organized effort in this direction was the creation of the Indian Association for the Cultivation of Science (IACS) in January 1876. The main person behind this venture was Mahenderlal Sircar (1833–1903), who was a trained doctor. Sircar stated that 'the object of the Association is to enable natives of India to cultivate science in all its departments with a view to its advancement by original research, and [as it will necessarily follow] with a view to its varied applications to the arts and comforts of life' (IACS, 1976: 9).[6] This organization played an important role in the promotion of advanced research after the turn of the present century, which facilitated C.V. Raman to obtain the Nobel Prize in physics in the 1930s. A direct spin-off of the IACS was the creation of four institutions for promoting technical education in 1902. Sathishchandra Mukherjee, a leading educationist of Bengal, launched the Dawn Society in 1902 to promote national education.[7] The society's magazine, *The Dawn*, provided an important forum for the popularization of science and literature.

The national education movement was however not confined to the Bengal region. The Poona Sarvajanik Sabha's demand of 1882 to strengthen higher technical education was taken up by the Indian National Congress after 1885, which passed recurrent resolutions to this effect in its succeeding sessions. In the princely State of Baroda, Sayaji Rao Gaikwad III established Kala Bhavan in the 1880s, the biggest technical institute established by a native state at that time. The engineering faculties of the M.S. University, Baroda, owe their origin to the Kala Bhavan, which was also instrumental for the development of Baroda as an industrial town by the 1920s. Between 1870 and 1920, the native Indian and missionary contributions to the establishment of colleges and the initiation of science teaching exceeded British colonial efforts.[8] In the nine universities established between 1857 and 1918—Bombay, Madras and Calcutta (1857), Punjab (1887), Banaras (1916), Patna (1917) and Osmania University, Hyderabad, (1918)—Indian contribution was substantial. By 1907, forty-five affiliated colleges were established in the three Presidency regions where ninety-one lecturers, most of them of Indian origin, conducted science and engineering courses at the undergraduate and postgraduate levels. Between 1910 and the 1920s, 2,134 degrees were awarded to Indian students in all the sciences (Mahalanobis, 1974).

A major break with colonial science teaching set in with the efforts of Mahenderlal Sircar, Nilratan Sircar and J.C. Bose, which resulted in the setting up of the Science Degree Commission in 1898. This Commission recommended the introduction of separate science courses and degrees. The colonial government however refused to finance postgraduate research in science at the Calcutta University in 1913. At this stage, the donation of over Rs. 4,000,000 by Taraknath Palit and Rash Behari Ghosh made it possible to establish the University College of Science and Technology at the Calcutta University, which was supported by Aushutosh Mukherjee, Vice Chancellor. The Palit and Ghosh Chairs in physics and chemistry by the 1920s at the University College acquired professionally prestigious status. Besides this initiative, including the earlier creation of the IACS, there were many other important contributions.[9]

As encouragement from the government in the form of scholarships to train Indian students in specialized fields of research was not forthcoming, a number of such berths and endowments were created by wealthy Indians. Parallel to the creation of science institutions and scholarships for advanced research, popularization of science and translation of modern science publications into local languages received attention from the Indian intelligentsia, widely supported by the missionaries and British supporters of the Indian cause. There were about a dozen science soiceties;[10] and as the detailed study of Bhattacharya et al. (1989) shows, there were 2,124 science publications in Indian languages between 1875 and 1896. The Calcutta Book Society, formed in 1817, contained 333 titles in various fields of S&T.

## Formation of Specialist Groups: Genesis of the Indian Scientific Community

With J.C. Bose and P.C. Ray joining the Presidency College in 1885 and C.V. Raman joining the IACS in 1907, the 'cultivation' of science was transformed into the 'advancement' of science with the formation of specialist groups for the first time. While the objective of advancing science meant a form of 'struggle' in the colonial context, these efforts were also meaningful from the point of the cultural traditions of India. The goal of advancing science by the Indian scientists at the turn of the century re-oriented them to link modern science tradition with the rational and experimental traditions of Indian culture. The assertion that the method of science is Western and hence alien to the Indian tradition was rejected by the leading Indian scientists of this era. P.C. Ray's two volumes on *The History of Hindu Chemistry* (1902) and Binoy Sarkar's *Hindu Achievements in Exact Science* (1918) are examples of this orientation. Modern science in a large measure helped in achieving a new status, both for self and national prestige.

J.C. Bose's work on microwaves (1895) and plant physiology (1900) earned him worldwide recognition and he was elected to the Royal Society in 1920.[11] Between 1900 and 1920, Bose was instrumental in developing a group on plant physiology after his paper 'Generality of Molecular Phenomena Produced Electrically in Living and Non-living Matter'. Bose published four monographs through Orient Longman on 'Response in the Living and Non-living' (1902), 'Plant Responses as Means of Physiological Investigation' (1906), 'Comparative Electro-physiology' (1907) and 'Researches on Irritability of Plants' (1913). With this base, Bose organized a research group on plant physiology at the Presidency College and later at the BRI from 1917. N.N. Neogi, S.C. Das, G. Das, J. Sircar, S.C. Guha and L.M. Mukherji collaborated with Bose. Bose, in all, published ninety-seven papers on various aspects of plant physiology between the period 1895 and 1920, and collaborated with nine researchers, including those mentioned earlier, in a quarter of the publications. From 1917, the Bose Institute launched its own journal called the *Transactions of the Bose Research Institute*.

In the field of chemistry, P.C. Ray discovered mercurous nitrite in 1896 working in the laboratory of the Presidency College. By this time, Ray was elected as the vice president of the Edinburgh Chemical Society. Ray obtained his doctorate in the field from Edinburgh University. After teaching and researching in chemistry for over thirty years at the Presidency College, Ray joined the Calcutta University College of Science in 1916. For the first time, what is known as the Indian school of chemistry emerged by the 1920s.[12] By the 1930s, the active publishing community in chemistry constituted about 200 scientists. Ray and other chemists such as S.S. Bhatnagar and J.N. Mukherjee were instrumental in launching the Indian Chemical Society in 1924, which also launched a journal from the mid-1920s. The credit for the first advance in research in physical chemistry in India goes to N.R. Dhar, who made original contributions in electro-chemistry. J.C. Ghosh's theory on the abnormality of strong electrolytes earned him world recognition and the credit for advancing research on colloid chemistry in India goes to J.N. Mukherjee and later to Bhatnagar. The school of chemistry under the leadership of Ray contributed to four generations of chemists in various Indian universities from 1915.

In physics, C.V. Raman, J.C. Bose, S.N. Bose and M.N. Saha constituted the Indian school of physics in the 1930s, but it was Raman who gave the lead during the first-quarter of the present century. The centenary volume of the IACS recognizes this development as the 'school of Raman'. Under the leadership of Raman, for the first time, physics acquired a professional status at the IACS and an Indian identity in the international sphere of physics was established with the award of the Nobel Prize to Raman in the 1930s. Raman and his associates published in reputed journals such as *Nature* and *Philosophical Magazine*, but the IACS launched its own journal, *Bulletin of the Association*, from 1909 which became an important outlet for publishing original Indian contributions.[13] In theoretical astrophysics, Saha's theories of thermal ionization and radiation led to the physical theory of stellar spectra by the 1920s. Saha's work on 'Ionization in the Solar Chromosphere' (1920) led to the growth of the 'ionospheric school' at Allahabad University, where Saha spent seventeen years. Saha's basic work was further advanced by S. Chandrashekar, D.S. Kothari and J. Majumdar who studied problems connected with the atmosphere of stars, application of the Fermi-Dirac statistics to elucidate the internal structure of stars and Kothari's theory of pressure of ionization (see Prasad, 1938; Sen, 1954). S.K. Mitra's recognition in the 1930s on radio science and chemical physics devoted to the interpretation of absorption spectra owes its initial impetus in the physical sciences from the turn of the century.

At St. Xavier's College, Father Lafont was instrumental in organizing a research group on spectro-telescopic investigations and, in contrast to the 'data-supply' nature of colonial scientific research, Lafont set up research facilities. During the transit of Venus, Lafont collaborated with the famous Italian astronomer, P. Tacchini, in the astronomical investigations at Madhupur, Bihar. Tacchini was instrumental along with Lafont in erecting a spectro-telescope at St. Xavier's College. Father V. de Campigneulles joined Lafont in 1882 on the spectro-telescopy work and published two books based on the studies of the famous total solar eclipse of 1898 by a team of Jesuit scientists. It may be pointed out that Indian developments in the field of modern astronomy began from the eighteenth century in Jaipur with the pioneering efforts of Sawai Jaisingh in the construction of astronomical instruments and tables.

In the area of mathematics, the pioneering efforts of Master Ramachandra from the mid-nineteenth century and the recognition of Ramanujan for the 'number theories' as a result of his collaboration with Hardy at Cambridge, preceded the professionalization of the field from about 1900. The Calcutta Mathematical Society was established in 1908 with Ashutosh Mukherjee (a leading lawyer of Calcutta and vice chancellor of the Calcutta University) as its president. Little known about Ashutosh was his original contribution to differential equations known as 'Mukherjee Theorems'. Ashutosh became a member of the London Mathematical Association and Cambridge University honoured him by including his theorems in their curriculum. Through the efforts of V. Ramaswamy Iyer, the 'Analytical Club' at Fergusson College, Poona, was upgraded as the Indian Mathematical Society in 1911. In 1914, the Rash Behari Ghosh Chair of applied mathematics was created at the University College of Science and Technology, Calcutta. Ganesh Prasad, the first DSc of Allahabad University, was appointed to the Chair.[14]

The constitution of specialist groups in various fields of research in the universities and specialized research centres enabled Indian scientists to assign a distinct identity to Indian science, and paved the way for the embryonic emergence of the Indian scientific community. Scientific achievements, including the advancement of science and its professionalization, which remained a dream during the lifetime of the founder of the IACS, M.L. Sircar, signify a significant departure from the colonial science structures. India could publish only eighteen papers in the journal of the Asiatic Society during 1836 and 1895. The British scientists, on the other hand, published 1,021 papers (Visvanathan, 1985). In the next twenty-five years, up to the 1920s, Indian scientific output accounted for over 350 papers. Together with the efforts to establish research groups, another major step in the professionalization of science in India was the creation of the Indian Science Congress Association (ISCA) in 1914. Beginning with a membership of sixty scientists in 1914, this body expanded quickly to 300 members in 1916, 360 in 1920 and about 760 in the 1940s. In 1914, thirty-five papers were presented at its annual session, which grew to 120 per year for the 1920s and about 180 for the 1930s.

The ISCA served as an important platform to catalyze 'community' consciousness as well as to unify the scattered specialist groups on a national scale during its annual conventions which took place in different parts of the country. During its formative period in the 1920s, the ISCA was instrumental in helping to organize and establish various associations in science disciplines through its sectional committees. Beginning with the formation of the Indian Botanical Society in 1920, the drive for the professionalization of science was further enhanced. By the 1940s, seventeen more societies and professional associations were created on an all-India basis covering all the major disciplines, which also launched journals in their respective disciplines.[15]

## Post-Independence S&T Growth: 1947–1980s

By the time India achieved independence in 1947, the Indian scientific community, though small in a relative sense, was well organized in physics, chemistry, mathematics, medicine, geology and the biological sciences. There were many leading scientists in these disciplines who were already recognized in the international sphere. Compared to other developing countries, the problems in the organization of science for India concerned a different dimension than the initial institutionalization of science processes. These related to the building of S&T infrastructure in some crucial areas of development and further expansion of S&T institutions which had languished under the colonial regime. India was rather fortunate in having the leadership of Bose, Madanmohan Malaviya, Nehru, Maulana Azad and many others who showed keen interest in the development and use of S&T for Indian problems of development from the pre-independence days. The support and involvement of this political leadership of the Congress Party for the national science phase forged close links between science and politics.

Given these pre-1947 links (see the two quotations from Nehru and the Congress Party at the beginning of this paper), the 'ideological' perspective of the national science phase directed the political and scientific elites to strengthen the indigenous S&T base after 1947. This combined elite, influenced and driven by the National Movement, believed that without economic independence, political independence lost its practical meaning, and that the planned economic programmes of industrialization and rapid economic growth on self-reliant lines could be sustained only through the strengthening and expansion of an indigenous S&T base. The 'optimism' of the instrumental role of S&T for development reflected unbounded legitimacy in the S&T policy discourse of the 1950s era. When Nehru took over as prime minister in 1947, he embarked on the building of S&T infrastructure. Here, the close 'alliance' that Nehru developed with eminent Indian scientists is an important feature from the sociological perspective, as it unfolds the S&T areas and institutions prioritized for support and the areas which were relatively neglected in receiving political support.

Immediately after independence, Nehru at the Indian Science Congress in 1948 (with few exceptions which he regularly attended) called upon scientists by observing that, 'in India there is a growing realisation of this fact that the politician and the scientist should work in close cooperation'. In contrast to Gandhi's religious orientation and his views which were in a large measure understood as being relatively opposed to modern technology, Nehru's modern, liberal 'image' and his explicit orientation towards modern S&T made him a 'messiah' of modern Indian S&T. The scientific community in general, and the elite in particular, identified with Nehru's vision of science, for they also found a great promoter of their interests. India's science policy after 1947 reflects the informal personal relations that Nehru had with Homi Bhabha in the atomic energy establishment, S.S. Bhatnagar and later Hussain Zaheer in CSIR, J.C. Ghosh and P.C. Mahalanobis in the Planning Commission and D.S. Kothari in the defence related area (see also Morehouse, 1976; Ahmad, 1985). The science–politics 'nexus' under the leadership of Nehru contributed to S&T infrastructure growth and in assigning an important role to S&T in the political agenda. It is not surprising then that though Nehru was instrumental in chalking out planned economic development through the Five-Year Plans, India's first ever Five-Year S&T plan (1974–1979) came into being only in 1973. Even though Nehru consulted and interacted with a wide section of the Indian scientific intelligentsia, the enduring relationship these elite scientists had with Nehru, as we shall see, was of special significance for the growth of science in certain specific directions.[16]

As early as 1948, Nehru created the Ministry of Scientific Research and Cultural Affairs and took on the portfolio himself. Compared to the pre-1947 period, as seen in the previous section, the locus for building and expanding S&T infrastructure in the post-1947 period got shifted to government administered science agencies. The period between 1948 to the early 1960s witnessed rapid expansion of the science base through agencies such as CSIR, Department of Atomic Energy (DAE) and the Defence Research and Development Organization (DRDO), and is also reflected in the science budgets as shown in Tables 9.1 and 9.2.

The CSIR (created in 1942) had no independent laboratories worth mentioning in 1947, but by the 1950s a network of fifteen national laboratories in the physical, chemical, engineering and biological sciences were created chiefly due to the efforts of S.S. Bhatnagar and the support he received from Nehru. As is generally referred in India, this development is known as the 'Nehru–Bhatnagar effect' (see Krishna, 1993b). At present, there are about thirty-five national laboratories under the umbrella of CSIR involved in various S&T areas. From a small number of 100 R&D personnel in 1947, the CSIR had grown to 2,000 in the 1960s and to 6,000 in the 1980s.

The 'Nehru–Bhatnagar effect' has a parallel in the growth of atomic energy establishments under the leadership of Homi Bhabha from 1954, when the DAE was created. Bhabha was so influential that he could

TABLE 9.1
**R&D Expenditure by Major Science Agencies**

*(million Rupees)*

| *Agencies* | *1958–59* | *1970–71* | *1980–81* | *1986–87* | *1990–91* | *1992–93* |
|---|---|---|---|---|---|---|
| CSIR | 51 | 215 | 690 | 1703 | 1893 | 2963 |
| DAE | 76 | 287 | 734 | 1658 | 2755 | 3166 |
| DRDO | 15 | 175 | 797 | 6586 | 7376 | 7930 |
| ICAR | 37 | 183 | 974 | 1625 | 2762 | 3380 |
| ICMR | 5 | 21 | 90 | 400 | 469 | 429 |
| DOS | – | – | 560 | 3095 | 3862 | 4909 |
| DST | – | 84 | 406 | 1103 | 1235 | 1606 |
| DOE | – | – | 54 | 56 | 61 | 180 |
| MOEn | – | – | 37 | 901 | 1620 | 2178 |
| DNES | – | – | 41 | 240 | 160 | 138 |
| DBT | – | – | – | 105 | 413 | 588 |

**Source:** *Data Book (1992)*, New Delhi: DST.

TABLE 9.2
**National Expenditure on R&D**

*(million Rupees)*

| *Item* | *1958–59* | *1970–71* | *1980–81* | *1987–88* | *1990–91* | *1992–93* |
|---|---|---|---|---|---|---|
| Expenditure | 221 | 1390 | 7600 | 28530 | 41860 | 56110 |
| % of GNP | 0.17 | 0.35 | 0.62 | 0.98 | 0.89 | 0.83 |
| Total Government | – | – | 6391 | 25421 | 36600 | 49612 |
| Total Private | – | – | 1209 | 3100 | 5260 | 6498 |

mobilize Nehru for setting up the DAE headquarters in Bombay where Bhabha resided. This was an exception to other science agencies, which had their headquarters in Delhi. The CSIR and DAE witnessed rapid expansion during the years up to the 1960s. While CSIR was considered the main agency to promote industrialization within the overall national economic strategies of import-substitution and self-reliance, the DAE was deemed as a long-term solution for India's energy and strategic requirements. From the point of technological capability in new areas, as Parthasarathi (1979: 47) observes,

> DAE represents the first beginnings of a technology capability in India. Though it set up institutions called 'research centres', these were full 'innovation chain centres', that is, they extended right out from basic research through applied research, engineering development, pilot plants, demonstration plants and industrial operations, all under the single umbrella of the Atomic Energy Commission.

DAE established twenty research institutions in various areas of atomic energy including the prestigious Bhabha Atomic Research Centre and the Tata Institute of Fundamental Research (TIFR) at Bombay.

Towards the late 1950s, while these two science agencies expanded and the higher educational base in S&T also witnessed growth in terms of universities, the situation became conducive for further expansion in other areas of science. At this stage, in 1958, Nehru deemed it appropriate to make a commitment for the support of science and its application as a matter of state policy. In consultation with Bhabha, Nehru drafted a Scientific Policy Resolution (SPR) which was passed by Parliament in 1958. As Rahman (1983: 1) observes, 'the SPR was both a testament of faith in science and a vision of society'. In the 1950s, India was the only developing country to have adopted such a resolution which provided both the social and political legitimation for further expansion of S&T infrastructure.

The third major organization in science that was created in 1958 was the DRDO, structured in somewhat a similar way as CSIR. DRDO started off slowly, with about five laboratories in the 1960s. It was the two wars that India was involved in the 1960s and the demands imposed by these events which led to the expansion of DRDO. It has about thirty-three laboratories involved in various S&T areas related to defence. D.S. Kothari, who made contributions in the area of physics, was the main advisor under Nehru for the expansion of DRDO. Though not as influential as Bhabha and Bhatnagar, Kothari was part of the close 'science circle' of Nehru and was also given charge of the educational reform commission in the 1960s.

Thus, for about two decades after independence, the real expansion of S&T infrastructure took place in the agencies of CSIR, DAE and DRDO. Even though the government had created science advisory bodies to the Cabinet as early as the 1940s and the Planning Commission (the body responsible for economic plans which had direct implications for S&T areas) in the early 1950s, Indian science policy reflected an informal basis of relationship between the elite scientists and the political leadership. As late as 1974 such a perspective governed S&T growth as pointed out by Parthasarathi (1974)—an important technocrat in the government:

> It is perhaps not surprising to find that decisions regarding the allocation of scientific resources, for example, have been taken not on the basis of the advice tendered to the political leadership by either of these bodies, but as a result of informal and tacit interactions between concerned individuals in the scientific community, the executive and the polity.

Under such a perspective of an informal basis of science policy, specifically those institutions (such as DAE and CSIR) which were led by the elite who could command resources from the government witnessed considerable growth (see Table 9.2). With hindsight, as the S&T institutional growth trajectory reflects, the areas of agriculture and medical research were two important domains of Indian S&T which witnessed only marginal prospects till the late 1960s. Perhaps, the relative absence of leaders such as Bhabha and Bhatnagar in the Indian Council of Agriculture Research (ICAR) and the Indian Council of Medical Research (ICMR) did not aid these areas of research as the other agencies. It is not surprising that the 'grand old' agriculture scientist, B.P. Pal (1977: 50), lamented

> how much the application of science to agriculture might have advanced if Nehru had been directly associated with the ICAR in the way in which he was associated with the CSIR and DAE. It is a pity that when these modern scientific organisations were set up, the older ICAR was not drastically reorganised on similar lines.

Even though the ICAR was created under the colonial government in 1929, it progressed for a while, but continued to relatively stagnate and languish till the 1960s. In 1964, ICAR was a small 'bureaucratized' unit in the Ministry of Agriculture and there was very little connection between the ICAR and the agriculture productive sector, including agriculture extension. From the beginning of the Green Revolution period from the early 1960s, ICAR drew tremendous attention with rapid expansion of its research and extension centres. The budget of ICAR was increased substantially from Rs. 37 million in 1958 to 183 million in 1970 and further enhanced to 329 million in 1975. There was an almost three-fold increase in ICAR's budget between 1975 and 1981 to about Rs. 974 million in 1981. This period also witnessed the establishment of five new agriculture universities and an extension of the existing Indian Agriculture Research Institute, which was revamped with the setting up of a postgraduate school through the assistance of the Rockefeller Foundation on the pattern of the Land Grant College System in the USA. The same pattern was followed in the establishment of new agriculture universities in Pantnagar, Ludhiana, Hisar and Hyderabad. The Land Grant pattern entailed a greater concentration of field research in the context of farmers and an extension agency to augment the 'two-way traffic' in applying new S&T inputs to meet the needs of rapidly developing agriculture. As Pal (1977: 52, 53) recognizes, these new agriculture universities were an 'important agency contributing to the attainment of the green revolution . . . . In fact, it is the coming of the agricultural universities that made it possible for the ICAR to successfully launch its all-India coordinated projects'. This concept of all-India coordinated projects was, however, developed by the ICAR and this pattern was aligned with the Land Grant pattern in the integration of the Green Revolution. There are about twenty-seven research institutions under ICAR in various areas of agriculture and forest related fields.

The introduction of Mexican and other hybrid varieties of wheat with the development of S&T infrastructure in genetic engineering, soil science, water technology and other agriculture related research processes entailed a demand for other inputs to absorb the concept of the Green Revolution. These inputs included agro-chemicals and fertilizers, farm machinery including tractor production, and the expansion of energy and irrigation schemes to effect improvement in food grain production. Between 1960 and 1980, India witnessed rapid expansion of fertilizer production based on foreign technology in the public sector companies. R&D centres in fertilizer production and design were set up in this period for the development of indigenous capabilities in this area.

In the area of medical research, the Indian Fund Research Association (IFRA) created by the colonial government in 1911 was redesignated as ICMR in 1949. Compared to the growing needs of India's population in public health, nutrition and medical services, ICMR could draw only a marginal support of Rs. 5 million per year in 1958, which was increased to 21 million in 1971 and to 33 million in 1976. There are eighteen research institutions under ICMR and about thirty-five institutions of research in various areas of health and medicine under the Ministry of Health and Family Welfare.

The era of close alliance between science and politics characteristic of the Nehru period (up to the mid-1960s) was transformed during the reign of Mrs. Gandhi after the early 1970s. Even though the alliance continued in varying forms in the administrative decision making of S&T, the growth of new science agencies and institutionalization of new thrust areas of S&T were, however, not determined by the elite personalities in science as in the earlier period. Various processes of S&T planning beginning with the creation of a National Commission on Science and Technology (NCST) in 1972 and the launching of the first S&T Plan (1974–1979) may be said to have influenced the further expansion of S&T growth. As argued elsewhere, from the science policy perspective, the period after the 1970s is significant from the point of 'S&T in policy' compared to the 'policy for science' perspective of the pre-1970 period.[17] What was also significant in this context was the enhanced voice of the public discourse on S&T, including the discourse on the questioning of the fruits of Indian science for development.

The 1970s, particularly the early period, witnessed the emergence of three major science agencies. The Department of Electronics (DOE) was set up in 1971 as a result of the Cabinet decision to give a thrust to this potential area. The DOE was deemed as a nodal agency for the planned development of the electronics industry, which would catalyze the process of self-reliance in this critical area in the shortest possible time. The second major agency which came up in this period was the Department of Science and Technology (DST), also in 1971. The DST's main objective was to primarily deal with new areas of S&T development, to fund basic research in science and engineering, to serve as a coordinating agency for inter-agency major programmes and to promote the development and utilization of domestic technology in all sectors of S&T. DST has eighteen research institutions under it. Some of India's premier institutions in basic research such as the IACS, BRI, Raman Research Institute, Institute of Plasma Research, and the Indian Institute of Astrophysics, among others, were placed under the DST in the 1970s. DST also has the responsibility of funding India's major science academies and ISCA. The third major agency that came up in this period was the Department of Space (DOS) in 1972, which may be said to have resulted as a spin-off from the DAE. India's space programme since the 1950s was administered by the DAE till 1972, when the Space Commission was also set up along with DOS. By the 1970s, the entire spectrum of science agencies, with the exception of the ICAR, was under the portfolio of the prime minister. In 1976, India's R&D budget of Rs. 2,237 million was dominated by the three science agencies, viz., DAE (24 per cent), DRDO (23 per cent) and DOS (16 per cent), which accounted for about 63 per cent of the total; whereas the CSIR and ICAR accounted for 16.5 per cent and 14.7 per cent respectively, and the rest of about 14 per cent was shared by the newly created science agencies mentioned.

During the period from the late 1950s up to the 1970s, the S&T infrastructure scenario also included the substantial efforts which went into the building of what may be termed the techno-industrial capacity, which was related to the establishment of consulting, engineering and design organizations (CEDOs). As shown by Parthasarathi (1979), there were forty-two CEDOs in the private sector and eight in the public sector by the late 1970s. These agencies were created to accomplish the coupling of the S&T segments in the process of capital goods production; absorption of foreign high technology in major areas such as power, steel, cement, oil exploration and refining, fertilizer production, chemicals and metallurgy; and to complete turnkey processing, plant design, engineering, erection and commissioning of plants in the major sectors of S&T.

During the 1980s, the issues of environment, alternative and new sources of energy, new sources of mineral resources and the promotion of new technologies such as biotechnology came into focus in the S&T policy discourse. The political support of Mrs. Gandhi in the early 1980s and later the support of Rajiv Gandhi from the mid-1980s to these areas of R&D led to institutional and infrastructure development. By 1980, two new science agencies, viz., the Ministry of Environment and Forests (MOEF) and the Department of Non-Conventional Energy Sources (DNES) were created with moderate annual budgets of Rs. 37 and 40 million in 1980–1981 respectively. India's decision to establish a permanent research station at Antarctica and explore new sources of mineral wealth from the oceans led to the creation of the Department of Ocean Development (DOD) in the early 1980s with a substantial annual budget of Rs. 493 million for 1982–1983. By the mid-1980s, the National Biotechnology Board created in the early 1980s under the chairmanship of the prime minister was upgraded as the Department of Biotechnology (DBT) with an annual budget of Rs. 105 million for 1986–1987.

Unlike the era of Nehru, when elite science personalities such as Homi Bhabha and S.S. Bhatnagar could mobilize political support to 'push' their programmes of research with considerable autonomy to structure the DAE and CSIR, the elite science groups during the regimes of Mrs. Gandhi and Rajiv Gandhi in the 1980s may be said to have largely depended on political 'push' for the creation and expansion of science agencies.[18] For example, the area of alternative and non-conventional sources of energy, which drew the attention of the scientific leadership since the 1950s in view of the needs of India's industrialization programme, could not have a separate departmental budget till the political 'push' given in the early 1980s. Even in the conventional areas of energy, the preoccupation with atomic energy somehow transcended the policy attention to long-term research planning on coal, in which India is endowed with substantial deposits. Historically speaking, another sector which met the consequences of the science–politics nexus of the Nehruvian era is the relative stagnation in the proportion of R&D funds for research in the university sector compared to the mission-oriented science agencies. The expansion of higher education in S&T through the expansion of universities, however, received substantial support.

From about twenty-five universities in 1947, there was a rapid increase to eighty in 1969, and to 160 universities and 5,723 colleges affiliated to these universities in 1989. Much of this growth followed the significant step taken by Nehru and his education minister, Abul Kalam Azad, in the setting up of the University Grants Commission (UGC) in 1953 under the chairmanship of S.S. Bhatnagar, who was also the person behind the growth of CSIR. The growth of the university base to obtain trained scientific and technical personnel however followed the recommendations of the Scientific Manpower Committee set up in 1947, which was represented by Bhabha and Bhatnagar among other scientists. While the well-paid scientific 'civil service' in the full-time science agencies such as DAE, CSIR and others drew adequate research budgets for higher research in their national laboratories, the university sector did not receive the same encouragement in higher scientific and technological research (see also Shills, 1969).[19] Even in the setting up of infrastructure for teaching and related research in the universities, the elite, urban universities in metropolitan cities such as Delhi, Calcutta, Madras and Bombay drew more support compared to the universities in the provincial and rural towns.

In the area of engineering sciences, there were thirty-eight colleges with 2,940 seats for the first degree courses in 1947. By the 1970s, the engineering colleges were increased to 138 with a capacity of 25,000 seats for the first degree level and 4,000 seats for the postgraduate level. The elite–provincial divide in the support of infrastructure for teaching and research is also discernible in the engineering university sector. While the five elite Indian Institutes of Technology (IIT), somewhat modelled on the MIT of USA, since the early 1950s drew support both from the government and countries such as West Germany, USA, UK and USSR, the regional engineering colleges enjoyed a lower status. The engineering colleges attached to the metropolitan universities, on the other hand, fall in between the two segments. The IITs, which enroll 2,000 students on an all-India competitive basis, produce the best Indian engineering students, but as the studies on brain drain from the Madras and Bombay IITs indicate, the net annual outflow of IIT graduates to the West (mainly USA) during 1970 and the 1990s has been on an average of over 30 per cent (see *Nature*, 16 December 1993, p. 618).

In the post-independence period, the university sector in a large measure, with the exception of the agriculture sector, was deemed more as a source of trained S&T personnel rather than a potential source of research production. Even though agencies such as CSIR from the 1950s supported about 500 doctoral and post-doctoral positions in the university sector (which in the 1980s increased to about 2,000 positions), there was an unstated policy separation of research between the science agencies and the university sector. Estimates of research funding between these two sectors show that throughout the post-1947 period the university component of total R&D remained around 7 to 9 per cent, while the rest was shared by the science agencies. M.N. Saha, in the mid-1950s, appealed to the government 'to give up this policy of indifference, this policy of denial' for the growth of a research base in the university sector (see Sen, 1954). Bhabha (1966) also, perhaps, recognized the flaw in the policies as he observed, 'it cannot be disputed that the cost of building the national laboratories . . . has been the weakening of the universities by the drawing away of some of their good people, which is their most valuable asset'.[20] It may, however, be pointed out that these long standing policies between the university and science agency sectors have changed in the early 1990s following the new policy directions to enhance the collaboration and mobility of S&T personnel between the two sectors.

Compared to many developing countries, India's continued commitment to the support of S&T in various areas during the last four decades enabled the country to build a substantial S&T base. Science policy experts such as Long (1979) subscribe to India's growth as a 'rising middle power'. No less important has been the post-independence growth of a large scientific community measured in terms of scientific productivity, journals and specialist groups in S&T. We shall briefly turn to this aspect in the next section. Notwithstanding the growth scenario of S&T, we shall in the following section turn to the effectiveness of this community and the problems of technological capacity confronting this community.

## Locating the Indian Scientific Community in the 1980s

Having traced the emergence of the scientific community in its encounter with colonial science and the post-independence scenario of science and politics, including the growth of S&T infrastructure, it is pertinent here to map and locate the Indian scientific community, its connectivity to technological and economic capacity, and its strengths and weaknesses within the overall government administered science.

### Between Centre and Periphery: In Search of a New Status

In the ongoing discourse of centre and periphery in vogue in the social studies of science, particularly in the qualitative and scientometric analyses, the position of Indian science can be placed in between the two polarities.[21] The Braun et al. (1988a, 1988b, 1988c) indicators for world science output for 1981 to 1985 lend some support to this perspective. As their database shows, there are developed, industrialized countries such as USA, UK, Japan, Germany, France, Canada and Netherlands which account for a range of 1.68 per cent (for Netherlands) to 36.67 per cent (for USA) of the total world scientific output measured in terms of research papers for 1981–1985. On the other hand, we have a vast majority of developing countries such as Brazil, Egypt, Nigeria, Kenya, Thailand and Algeria which account for a range of 0.37 per cent (for Brazil) to 0.01 per cent (for Algeria) of the world science output of publications for the same period (1981–1985). By all means, even though India is a developing country, her scientific output in publications indicates a relatively 'middle range' figure of 2.68 per cent of the world output. Among the publishing nations, India ranks eighth in order above Italy, Australia, Netherlands, Sweden and other European countries. According to the data supplied in Braun et al. for 1981–1985, more than half the entire Third World scientific output (about 64 per cent), including countries like China and South Africa (but excluding Eastern Europe), comes from India. As Krishnan and Viswanathan (1987) observe from a detailed study on Indian journals, 'India accounts for more than half of all scientific journals published in the Third World. The range and scope of problems tackled by Indian scientists are way ahead of those done by other Third World countries and comes very close to those of the advanced countries'.

In terms of human resources in S&T, India is generally referred to be the third largest in the world. In the Third World, Indian professional infrastructure such as science academies, scientific societies, journals, universities and specialized research institutions, and in the institutionalization of new scientific fields and sub-disciplines, India is far ahead. Despite this, India's status however remains one of being outside the club of 'centre' countries but at the same time there remains the paradox whether Indian science can be called only a peripheral science. Some Indian social scientists, particularly the scientometricians and sociologically inspired scientists, over the last decade have relegated Indian scientific efforts to the Third World periphery.[22]

Methodology based on the Scientific Citation Index (SCI) alone (which however is mainly concerned with what is called 'international science' and advancement of knowledge) to characterize Indian science as periphery is too narrow a perspective. Such a perspective undermines the sociological and historical growth of science as a social institution, and the professional infrastructure available for the training and reproduction of the institution of science, including the important learning processes. Moreover, there are enormous differences between countries like India and other small developing countries for the development of 'science as a profession' which question the generalizations on the notion of peripherality (see for instance Eisemon, 1982; Gaillard, 1991). Even among the 'small' developing countries, notions of peripherality need to be contextualized in terms of different areas. For instance, the detailed study of Cueto (1989) on Andean biology in Peru raises important questions against the notion of peripherality.[23] As Eisemon and Davis (1989: 220) reviewing a number of periphery bound studies point out:

> such characterisation is too sweeping. Some Third World scientific communities are vigorous and inventive. Rapid expansion of local facilities for scientific research and training has resulted in the development of distinctive patterns of communication in which participation in local information networks is an integral component to participation in the international information networks.

Indian science appropriately fits into such a perspective. In the following section we shall look at a few features of Indian science in this light, which will also to some extent substantiate the growth of science in India as a 'middle range' community.

## Journals

Sociologically speaking, journals indicate and define boundaries for specialist communities, and their growth in terms of specialities and research areas also signifies the maturity of scientific groups in relevant areas of research. Similar to national academies, journals are important intellectual resources of national prestige and identity. At present, India produces about 1,500 journals in S&T alone. As already mentioned, India accounts for half of the Third World journals. Indian scientometric studies on journals indicate that about 500 Indian S&T journals are covered in various international abstracting and indexing services (see Sen and Lakshmi, 1992). Table 9.3 shows that beginning with eighty-four journals in 1950, there has been a gradual increase every ten years to 440 journals in 1990 which are covered in various international services. While only eleven journals are covered in the SCI in the 1990s, the figure was slightly better in the 1970s when thirty-six journals were covered in the SCI. While the charge of various studies, such as those of Arunachalam and Manorama (1988, 1989), Krishnan and Viswanathan (1987) and others, that Indian journals suffer from a low impact factor and inadequate peer review system is true, it is also true that the SCI under-values and under-represents Third World science in general and Indian journals in particular. The studies indicate that out of the estimated 5,000–6,000 journals in the world, the SCI covers only 5 per cent. About 700 journals (0.7 per cent) account for about half of all citations and 400 journals (0.47 per cent) account for about half of all published articles.[24] As such, much of the applied research papers published in local and national journals do not attract the attention of scholars in the 'club' of centre countries who are more concerned with frontiers.

**TABLE 9.3**
**Growth of Indian Journals in S&T, 1900–90***

| *Disciplines* | *1900–50* | *1951–60* | *1961–70* | *1971–80* | *1981–90* | *Total* |
|---|---|---|---|---|---|---|
| S&T General | 8 | 5 | 3 | 4 | – | 20 |
| Life Sciences | 49 | 48 | 58 | 69 | 35 | 259 |
| Physics and Chemistry | 10 | 11 | 21 | 20 | 7 | 69 |
| Mathematics | 6 | 3 | 6 | 8 | – | 23 |
| Engineering Sciences | 11 | 22 | 16 | 14 | 6 | 69 |
| Total | 84 | 89 | 104 | 115 | 48 | 440 |
| Journals covered in SCI | – | – | 26 | 36 | 11 | 73 |

**Source**: Based on Sen and Lakshmi (1992).
* Journals which are covered in one of the national and international abstracting services.

Moreover, such applied research papers might be based on previous knowledge which is five or ten years old or even older. In contradistinction to some scientometric conclusions, the fact that scientific knowledge, whether old or new, is brought to bear to solve a local problem, far from makes it a peripheral science. Rather, as economic historians argue, it is the applied spectrum of R&D which is more concerned with the problems of development and the economic success of various sectors. From the Third

World perspective, it is only a partial view to think about science as significant from fundamental or basic research parameters. The utility of science as Rosenberg (1990: 148) points out, 'comes from its ability to solve problems that are very elementary, indeed even uninteresting, from the point of view of the research scientists working at the research frontier'. In this light, the relative contribution of the agriculture science community for solving the problems of food production in India is a relevant case which defies the peripherality 'thesis' of Indian science. Thus, we need far more multi-dimensional and locally appropriate methodological tools to evaluate the definition of peripherality. This economic dimension of Indian R&D is dealt with separately in the last section.

## New Specialities and their 'Ecological' Impact

Beyond the impact factor, the growth of journals in a discipline in terms of specialities symbolizes the dynamic growth of specialist groups. Growth of advanced centres of research and training, emergence of a scientific elite, growth of societies and professional networks, organization of important professional seminars, networks of relationships with the scientific elite at the international level and, above all, a legitimacy and autonomy to draw and sustain financial resources in this era of 'big science' from the state refer to what may be termed as the 'ecological' impact of scientific fields. In many ways, these developments are also good indicators of the vibrant growth of science as a social system. Indian scientific growth presents us with a special case in the Third World, which has in the last four decades been able to generate this 'ecological impact' across the various disciplines of physical, chemical, mathematical, engineering and life sciences.

The growth of the biological sciences with reference to the emergence of research or specialist groups in India can be traced back to the turn of the present century to the pioneering efforts of J.C. Bose and others as seen in the first section. Out of 259 journals in the life sciences, there are fifty-three journals in the biological sciences alone. The growth of these biological science journals, as shown in Table 9.4, corresponds to the growth of specialities in this field. If we consider the publications in this field to be approximately one-third of the life sciences, then the figure works out to be about 7,000 papers. This is more than the combined total output in the life sciences of Egypt, Mexico, Thailand, Kenya and Algeria for the period 1981–1985. Due to limitations of space, we will briefly explore the 'ecological' impact of the growth of modern biology in the 1980s with reference to molecular biology and biotechnology. These sub-fields are considered for attention in this section as they have received substantial attention by the scientific community and government funding of research as an important strategy in science and future development.

TABLE 9.4
Growth of Journals in Different Specialities of Biological Sciences in India, 1900–80s*

| *Year* | *Speciality* | *First Journal* | *No. of Journals in the 1980s* |
|---|---|---|---|
| By 1990 | Biology/Botany | Calcutta Journal of Natural History | 16 |
| 1917 | Plant Physiology | Transactions of Bose Research Institute | 4 |
| 1910 | Genetics | Journal of Genetics | 3 |
| 1930 | Biochemistry | Biochemistry Review | 2 |
| 1951 | Phytomorphology | Journal of Phytomorphology | 1 |
| 1952 | Palaeobotany | Palaeobotanist | 1 |
| 1958 | Cytology | Journal of Nucleus | 3 |
| 1960 | Entomology | Bulletin of Entomology | 8 |
| 1961 | Microbiology | Indian Journal of Microbiology | 1 |
| 1962 | Phycology | Phykos | 1 |
| 1963 | Experimental Biology | Indian Journal of Experimental Biology | 3 |
| 1970 | Ecology and Environment | Indian Journal of Ecology | 7 |
| 1971 | Mycology | Indian Journal of Mycology and Plant Physiology | 1 |
| 1973 | Parasitology | Indian Journal of Parasitology | 1 |
| 1986 | Biotechnology | Journal of Microbial Technology | 1 |
| Total number of journals | | | 53 |

* Excludes journals specifically relevant to medical sciences.

MOLECULAR BIOLOGY: There are about fourteen advanced research centres in the field of molecular biology and twenty-five research groups involved in various research problems (see Table 9.5). The origin of molecular biology in India is traced to the pioneering work of G.N. Ramachandran (GNR) who had his initial training under India's only Nobel laureate in science, C.V. Raman, and later worked for few years at Bragg's laboratory at Cambridge in the 1940s. GNR, on his return in 1949 to India, initiated crystal structure studies at the Indian Institute of Science (IISc) and later also initiated X-ray studies at the physics department of Madras University in the early 1950s. Up to the 1960s, GNR's group worked on triple helical structures of collagen which led him to biomolecular structures and conformation resulting in a pair of peptide units in proteins and polypeptides that are said to have become text-book knowledge in molecular biology (Burma, 1992). From

TABLE 9.5
**Advance Research Centres in Molecular Biology in India**

| *Institutions* | *Year of Establishment* | *No. of Leading Scientists* | *No. of Groups* |
|---|---|---|---|
| IISc, Bangalore | 1970 | 12 | 3 |
| TIFR, Bombay | 1960 | 10 | 2 |
| CCMB, Hyderabad | 1980 | 20 | 5 |
| NII, Delhi | 1980 | 10 | 2 |
| AIIMS, Delhi | 1960 | 10 | 2 |
| NCL, Pune | 1979 | 10 | 1 |
| BHU, Banaras | 1982 | 5 | 1 |
| Delhi University | 1982 | 9 | 1 |
| Kamraj University | 1981 | 8 | 1 |
| Madurai University | 1979 | 12 | 2 |
| IICB, Calcutta | 1975 | 6 | 1 |
| Madras University | 1979 | 10 | 2 |
| IARI, Delhi | 1980 | 7 | 1 |
| JNU, Delhi | 1983 | 10 | 2 |

1970, GNR moved again to the IISc and organized a strong group in molecular biophysics. This research group has about twelve scientists and an equal number of PhDs have been produced during the last decade.

At TIFR—India's premier fundamental research institute in physics, maths and nuclear sciences—the origin of molecular biology goes back to Homi J. Bhabha (father of India's atomic energy programme), who through Leo Szillard identified an Indian, Obaid Siddiqui, in the 1960s. During that time, Siddiqui was working with renowned names such as Alan Garen and Melvin Cohn in USA. Under Siddiqui, projects in this field, particularly in the area related to neurobiology, grew rapidly and now has a group of ten scientists. Siddiqui was elected as a Fellow of the Royal Society, London (FRS) in the late 1980s.

The nucleus of India's main molecular biology laboratory—Centre for Cellular and Molecular Biology (CCMB)—goes back to the 1960s. P.M. Bhargava, the founder-director of this institute, organized an international symposium on 'Nucleic Acids Structure, Biosynthesis and Function' in 1964, in which a number of notable names in the field such as Benzer, Monier and others, including the famous Francis Crick, participated. This meeting and Bhargava's initial efforts in the field of biochemistry eventually led to the establishment of CCMB within the structure of CSIR in the early 1980s. In various research areas of this modern biology field there are about fifty full-time scientists and the laboratory enrolls about ten PhD students every year.

Another major institute which pioneered this field is the National Institute of Immunology (NII) through the efforts of G.P. Talwar. In various areas of immunology and related areas of molecular biology there are about sixty full-time scientists at NII presently. Talwar had close working contacts with Jacques Monod and did pioneering work in Segal's laboratory on binding of estradiol to DNA, and organized two major symposia in the field in the 1960s when he was head of the biochemistry department of one of India's premier medical institutions. Talwar is well-known for his development of anti-fertility and leprosy vaccines, which also earned him the highest award of France in the early 1990s.

At the Banaras Hindu University, this field has been institutionalized by M. Chakravarty and her husband D.P. Burma since the 1980s. Chakravarty had her initial training at the famous Coldspring Harbour Laboratory, USA, and through her contacts with Max Delbruck organized two key seminars on 'Molecular Basis of Host–Virus Interactions' in the 1970s. D.P. Burma worked in the USA in the 1960s with established groups in the field including the Nobel laureate Severo Ochoa at the New York University School of Medicine. The efforts of this couple led to the establishment of this field at Banaras Hindu University.

Similar efforts by other leading Indian biologists such as B.K. Bachawat for the expansion of the Indian Institute of Chemical Biology, Calcutta, and the institutionalization of the field at Delhi University, Rajamanikam at the Madurai Kamraj University, Madurai, John Barnabas and Mascarnehas at the National Chemical Laboratory, the recent efforts of G. Padmanaban and Sasisekharan at IISc, and V. Jagannathan and B.C. Guha at the applied chemistry department of Calcutta University have given rise to notable research centres in the field of molecular biology in India. Apart from these centres, there are about fourteen small research teams scattered in various university departments.

Over the last seventeen years, various groups and leading Indian biologists mentioned earlier organized about eighteen national and international professional symposia and meetings in various areas of molecular biology. The international participation in these meetings and the close contacts the Indian biologists developed with leading groups in the world, mainly as a part of their post-doctoral training, have played an important part in the professionalization of the field in India. No less important are the major Indian scientific societies in biology as we shall briefly see in the next section. These contacts the Indian biologists developed, some with Nobel laureates, were instrumental in several ways for the institutionalization of the field in India particularly at CCMB, TIFR, NII, IISc and the Banaras Hindu University (see Burma, 1992).

In the biological sciences, the two well-known societies which have sustained the 'spirit' of the community and intellectually supported the biological science community are the Society of Biological Chemists (SBC) established in the early 1930s and the Guha Research Conferences (GRC) which came into being in the early 1960s. Referring to many of the groups and institutions (mentioned earlier), Bhargava and Chakravarty (1991: 515) observe:

> Two organisations that helped to bring these and other small groups that subsequently came up all over the country with the opening of departments of biochemistry both in the universities and in the medical colleges, and also helped modernise the departments that related biological sciences of various kinds, were the SBC of India, which should be soon celebrating its 60th anniversary and the Guha Research Conferences which just celebrated their 30th anniversary.

As is known in biological circles in India, the GRC not only provides an arena to review the frontiers in the field and discuss the major developments in Indian biology but, as reflected by two leading biologists, GRC has played an important professional role to set the standards in excellence. B.K. Bachawat pointed out that even established scientists were suspended from the membership of GRC if they 'failed to publish good stuff and failed to attend the annual meetings'.[25]

As the detailed survey of the field of molecular biology by one of its leading scientist's Burma (1992) shows, India is no periphery to this field in the 1990s. Even though more than half the publications in this field from these institutions and groups find their way into the mainstream SCI covered journals, the efforts to revamp the Indian journals has drawn attention in the annual meetings of the two societies. The CSIR database shows that in a majority of the papers published in the SCI covered journals in the related fields of molecular biology the science citation index per paper for leading institutions ranges between 1.0 to 2.5.

Further, Burma's survey (1992: 224) also indicates the trend of return intellectual migration in this field, and points out that 'with the development of several schools of molecular biology in different parts of the country and return of a number of young enthusiastic, well trained molecular biologists from abroad the field is very rapidly growing'.[26] What is also significant in the growth of this field is the emergence of the inter-disciplinary oriented character which reflects the situation in the advanced, industrialized countries. With this development, particularly from the 1970s, a renewed and rejuvenated thrust has been given to the more application-oriented field of biology and biotechnology as well. As Balram and Ramaseshan (1991: 509) in their introduction to the special issue of the journal *Current Science* on biotechnology comment,

> Indian molecular biologists—a broad term that encompasses biologists of various persuasions: biochemists, biophysicists, crystallographers and

> even some poorly disguised chemists and physicists—have successfully ridden the bandwagon of the scientific revolution in this area in the West. In so doing, they have propelled themselves into the position of standard-bearers of the promised biotechnology millennium in this country.

Rather, as Burma (1992) puts its, the growth of molecular biology greatly influenced the establishment of the high powered DBT in the early 1980s. Given the close nexus between these two fields of biology, it is relevant here to briefly explore some institutional features and significant developments in the area of biotechnology in India during the last few years.

BIOTECHNOLOGY: In parallel to molecular biology, the growth of biotechnology in India received considerable attention and support mainly from the DBT and DST's basic research funding body. The current funding of biotechnology research is about Rs. 120 million per year. As Padmanabhan (1991: 511) points out, 'for a government outfit, DBT has been extraordinarily active, vibrant and forward looking'. During the last decade, through DBT's support, biotechnology groups have been organized in about thirty institutions both in the university and science agency laboratories such as CCMB, National Chemical Laboratory and IISc.[27] In an effort to develop skilled S&T personnel in this new area, support in the university departments has been channelized for postgraduate and doctoral level research. About twenty universities now offer MSc/MTech and doctoral programmes. The DBT also sponsors short-term courses and training programmes of up to four weeks in high technology specialized areas in institutions where such expertise is available. To develop technicians, two-year diploma courses for undergraduate BSc holders have been initiated. Over a 1,000 persons received training during the 1980s. At the school level, efforts have been made to generate interest in this field through support for organizing lectures, demonstrations and short-term training programmes, both for school-children and teachers. The DBT provides ten scholarships for high school students for taking up biological sciences at the university level.

In an effort to keep the scientists abreast of the advanced R&D in the fields of modern biology and related fields, the DBT has also sponsored Distributed Information Centres (DICs) in nine university and R&D laboratories involved in the area of biotechnology and closely related fields. The facility provided through the DICs is to access international databases. In addition, fourteen user centres have been created in different parts of the country with access mechanisms to make information available at universities, laboratories and manufacturing institutions. This access is provided through the Biotech Network (BTNET) linked to the DICs.

With the support rendered by agencies such as DBT and DST, the field of biotechnology can be said to have become highly institutionalized in the research and teaching institutions in India. The launching of the *Journal of Microbial Technology* in 1986 can be considered as an indicator of the growing professional status of this field. Further, as one of the leading biophysicist Padmanabhan (1991: 511) observes,

> From almost a zero level in the early eighties, we now have at least two dozen laboratories where good recombinant DNA expertise is available. At the technology level, the successful demonstration of embryo transfer in animals; development of antigen—antibody—DNA based diagnostics; RFLP analysis and DNA-fingerprint analysis; and the cloning of a variety of genes attest to a high level [of] competence in modern biotechnology.

With government support and its positive intervention in this new field, even though the biotechnology community developed considerable research capability, there is a growing concern about the lack of an adequate atmosphere for its commercialization. As in the case of USA, the private industry thus far has only shown a residual interest in this field for the development of the industry. Padmanabhan (1991: 511) further sums up the situation as follows:

> The fact remains that many of the programmes are organisational efforts at coordination rather than implementation of high-technology knowledge. This effort should not be minimised in importance since the results will be seen to be reaching the people. But at the same time, I do not see even a single r-DNA-based protein product on the anvil for commercial production.

From an overall perspective, the specialist communities in molecular biology and biotechnology may be said to have achieved considerable visibility through research publications and interaction links at the international level. The professional growth of several groups in these fields over the last decade attracted established Indian scientists from abroad, who initiated many of the current established groups in India. Despite these achievements, as in many other scientific fields, Indian science represents a 'typical' case. It is not a situation of 'peripheral' science but at the same time falls short of the 'centrist' position prevailing in the industrialized world. The challenges confronting Indian science arise not from the 'input' side (that is, establishing viable institutions, groups, journals, infrastructure, etc.) but in overcoming the hurdles on the 'impact side' of the R&D circle. In other words, problems are inherent in the conversion of local scientific capability into technological capability for the commercialization of research. We shall look into this problem in a larger Indian context in the next section.

## The Scientific Community and the Problem of Technological Capability

The relation of a scientific community to the technological capability of a country may be better understood through the activities of R&D, on which a majority of the scientific work force is engaged. Given that India from the 1970s has been spending only about 10 to 15 per cent of its allocations on basic research and the rest of about 85 per cent on applied and development research, the bearing of R&D on technological capability is an important feature in exploring the problem of connectivity of the scientific community. Among the developing countries, Indian R&D expenditure as proportion of GNP increased remarkably from 0.4 per cent in 1975 to about 1 per cent in the late 1980s. Whilst defence and national security related research accounted for about 30 per cent in the 1980s, civilian R&D accounted for about 70 per cent. The R&D budget for 1990 was Rs. 46,160 million (approximately US$1,538 million). In this section we shall deal with civilian R&D, particularly industrial research.

The problem of technological capability from the Indian perspective finds a logical chord only when viewed against national economic strategies, before relating it to the R&D work of the scientific community. From such a stand point, viewed historically, Indian economic strategies formulated through national five-year plans beginning from 1951 (presently the Eighth Five-Year Plan is in progress) enunciated a development strategy which emphasized import-substitution and self-reliance oriented industrialization for a long time, up to the early 1980s. As a part of the national plans which contained directives for S&T, the official S&T policy discourse during 1950 and the early 1970s, the S&T plan of 1974–1979 and the Technology Policy Statement of 1983 emphasized self-reliance and import-substitution strategies in building scientific and technological capabilities. Self-reliance in S&T meant a capacity for autonomous decision making and implementation at all levels of S&T. Second, it did not exclude foreign technology, but as the S&T Plan of 1974–1979 stated, it meant the 'utilization of a mix of imported and indigenous scientific and technological resources: a mix in which the production of [the] indigenous component will steadily increase both in quality and more importantly in the number of critical national projects that are based upon indigenous technology' (NCST, 1973: 3.11). Complimenting the S&T plan, the Fifth Plan document stated that: 'Foreign collaboration must serve to supplement and accelerate the development and utilisation of indigenous technological and production capabilities in a manner which advances the country's effort to attain overall self-reliance as rapidly as possible' (Vol. 1: 35).[28]

India's industrialization programme from the 1950s, which was based on the importation of technology, covered all the major sectors of the economy such as power, chemicals, machine tools production, fertilizers, steel, cement and agricultural machinery, with a view to developing import-substitution technologies. The import policy was relatively liberal in the 1950s and 1960s. During these decades, as the first section shows, there was a rapid expansion of industrial research through agencies such as CSIR and in the public sector enterprises to some extent. As the import-substitution strategy started to pay dividends with the development of indigenous technologies in the areas of chemicals and drugs, fertilizers, food technology, agricultural machinery, etc., the import policy from the 1970s became somewhat restrictive.

Viewed with hindsight, India built up a large government administered public sector industry for industrial production in the areas referred to earlier with imported technology. Industrial policy from the 1950s gave the state an overriding role with regard to both regulation and promotion. The Industries Act of 1951 and the Industry Policy Resolution of 1956 which were passed by Parliament, initially reserved major sectors of the industrial economy for the state. At the same time, the Nehru-based 'mixed economy', where private and public enterprises coexisted within an overall 'socialistic pattern', also resulted in a substantial segment of private sector enterprises in textiles, chemicals, power, steel and in some other industries which were reserved for the public sector. Even the private sector was allowed to import technology which was regulated by the government bureaucracy.

The period during which public sector enterprises were built with imported technology, the government strategy at the same time attempted to develop indigenous technology. The R&D structure created and expanded was expected to relieve the imports for the succeeding stage or scale of technical know-how over a period of time in specific areas. It was also meant to develop appropriate capacity to absorb imported technology for production of goods which would in the process result in new or novel innovations, technical changes and improved efficiency of production. Towards this end, the CEDOS created and promoted in the public and private sectors beginning from the 1960s were to play a key role in the indigenization of production technologies.

When we examine the achievements of the scientific community through its R&D activities for the period up to the mid-1980s, there are many examples of relative success in the absorption of foreign technology and its replacement within the protected environment of government policies, particularly up to the period of the 1970s. As the situation progressed into the 1980s and particularly towards the end of that decade, the R&D capacity became increasingly under-utilized in the face of the government's introduction of the new economic policy of liberalization, which required new and competitive technological changes. As we will see, there are many institutional and structural reasons for the relative failure of R&D capacity. But first let us see the positive side of the spectrum.

The CSIR, where about 6,000 R&D personnel are working in about thirty-five national laboratories, contributed to import-substitution and self-reliance in many areas such as chemicals and drugs, physical standards in industry, food technology and agricultural machinery, among other areas. In food technology, the CSIR process on baby food developed in the mid-1950s replaced the multinational Glaxo by 90 per cent by the 1960s. This process led to the growth of a successful cooperative milk industry in the state of Gujarat known as AMUL, which produces baby milk food under the same name.[29]

In the 1960s, the CSIR laboratory, Central Mechanical Engineering Research Institute, Durgapur, designed and developed an indigenous tractor to meet the then growing demands of the Green Revolution. This technology, which was meant to become the 'flag' of the Indian public sector company, Hindustan Machine Tools Ltd., was made redundant by opting for foreign technology. The same technology, through the efforts of scientists and technologists who developed it, was commercialized by the Punjab state sector unit, Punjab Tractors Ltd. (PTL) by the 1970s. Commercialization of this technology was executed by the firm in a situation when at least ten multinationals produced tractors in India and this technology eventually became a success in the regions of Punjab, Haryana and parts of western Uttar Pradesh which are known to have first implemented the Green Revolution concept. PTL started with a 15hp low cost multifunction tractor called 'Swaraj' (symbolizing self-reliance) and now produces four ranges, viz., 15hp, 18hp, 35hp and 50hp (see Aurora and Morehouse, 1974; Chaudhury, 1986). In the area of chemicals and drugs, CSIR's National Chemical Laboratory, Pune, is an important case which successfully contributed to the import-substitution strategy of the government. As the study of Sandhya and Jain (1992) on the National Chemical Laboratory shows, the Laboratory, which employs about 700 scientific personnel presently, undertook 410 projects between 1965 and 1978. Out of these, 203 projects (about 50 per cent) related to import-substitution, which resulted in the commercialization of fifty-eight projects (about 20 per cent).[30]

Outside CSIR, the public sector companies in power, steel, fertilizers, oil and metallurgy which developed in-house R&D facilities between the 1950s and 1970s made many significant contributions to the import-substitution and absorption of foreign technology process.[31] By the early 1980s, India was a typical case in the Third World which through import-substitution and self-reliance in S&T strategies had developed technological capabilities to produce a vast range of industrial products indigenously. Much of the R&D efforts in CSIR and in other public sector enterprises were successful in areas and products in which the government intervened to protect through import and trade policies. Up to the early 1980s, while the government economic policies adopted a protective strategy to aid indigenous R&D capabilities to a large extent, this strategy was flexible enough to permit importation of technology for economies of scale in various areas such as power and fertilizers. This duality led to the 'redundancy syndrome' and protests, as demonstrated by the 'Swaraj' tractor case (see Aurora and Morehouse, 1974; Chaudhury, 1986) and the struggle launched by the power R&D technologists over the power industry's BHEL–Siemens deal (see Ramamurthi, 1978) in the late 1960s and 1970s respectively.

Notwithstanding such episodes, the Indian scientific community responded effectively to the national goals of self-reliance and import-substitution in science, particularly at those junctures when the purpose and goals laid down by the government were clear and which entailed participation by relevant scientific and technological personnel in decision making. Outside industrial research, the capability of the agriculture science community is demonstrated in the manner in which the concept of the Green Revolution was given a practical meaning and which enabled India to avert importation of food grains. But the situation has changed since the late 1980s with the new economic policies of liberalization in foreign investment and import of technology, which demand technological competition both at the national and global levels. Not only rapid technological changes but the factor of indigenous capability in introducing new innovations, which is reminiscent of Japan after the 1970s, has posed new challenges to the Indian scientific community.

The R&D capabilities developed for four decades after independence enabled India attain self-reliance in production for local consumption in many areas. The same cannot be said about the export-promotion and economic competitiveness capabilities in the 'high' and 'advanced' technology-based industries. Protective policies of the government coupled with the long gestation period of import-substitution and self-reliance in S&T, as assumed in the S&T policy discourse, did not result in new technological changes and innovations to aid technological competitiveness of Indian R&D. The relative isolation of R&D structures from the industrial and academic university structures in their post-independence growth, and the disjunction between the S&T policies and economic policies at the implementation levels in many ways contributed to the under-utilization of real Indian R&D capabilities. As Nathan Rosenberg (1990: 149) observes while reviewing various models for industrialization:

> India represents what appears to be a case of low pay offs from a relatively well-developed and extensive scientific and technological infrastructure. Specifically, it is widely accepted that by comparison with her agriculture research, which enabled India to approach self-sufficiency in

> food grain production in the late 1970s and early 1980s, industrial research in India has been distinctly disappointing. I believe that this has a lot to do with the extremely tenuous links between the various public and private institutions that are involved in the process.

A careful reading of Rosenberg's observation draws our attention to the under-utilization of Indian R&D capabilities, which is to do with the problem of linkages between various institutional settings involved in the generation of knowledge and production of industrial goods. In this perspective, however, three relevant features are worth paying some attention to as follows.

The first is the distribution and structure of the R&D effort. Government has been the major source for R&D activities for the last four decades, despite the existence of a large private sector. Even within the public sector, the expenditure incurred by its 190 enterprises has been very low. The public sector enterprises which account for about 25 per cent of India's GDP and a share of about 50 per cent of the Plan investment outlays from the 1950s to the 1980s contributed only 9.6 per cent of total R&D expenditure in 1991. The private sector contributed only 11.4 per cent in the same years. The national laboratories under the government account for about 73 per cent of the total R&D and the remaining 7 per cent is accounted for by the university sector. Thus, the low level of in-house R&D, both by the public and private sectors, coupled with their reliance on imported technology in many ways contributed to the under-utilization of Indian R&D capabilities.[32] Knowledge generated at the laboratory level, as Rosenberg (1990) stresses, needs constant R&D downstream trials such as pilot plant scale-ups, and designing and management of production for efficiencies in marketing. Lack of attention to these activities in relation to the R&D know-how available in the national laboratories prevented the possibilities for technological changes in the Indian case.

In agencies such as CSIR, with marginal exceptions, there indeed existed terrible R&D policy confusion in the up-scaling of its know-how. From the early period of CSIR's existence it had no clear-cut policy on pilot plants. As the detailed study of Visvanathan (1985) on the National Physical Laboratory of CSIR shows, the Laboratory scientists experienced confusion over their goal orientations. From the Laboratory view, this confusion with regard to the scale-up of research persisted as the know-how developed in the Laboratory was to be taken up for commercialization by the National Research Development Corporation (NRDC)—an intermediary government funded organization between research and industrial commercialization. Whereas the public expectations of CSIR demanded economically useful research, the practical conditions necessary in this direction were not articulated in the Laboratory's goals. This situation influenced scientists more towards 'cosmopolitan' or 'professional' goals (see Krishna, 1987). In a related context, two important viewpoints deserve attention. As Valluri (1993: 556), who spent more than thirty years as the director of the National Aeronautical Laboratory of CSIR observes:

> the government encouraged industry to set up production based upon imported know-how both in [the] private and public sectors. The policies to manufacture products under foreign licences to sell in what is virtually a sellers market have been a very serious disincentive for the industry to seek partnerships with Indian R&D or set up viable in-house R&D centres to bridge the gaps from lab level technologies to those required for production. Thus while the government is wondering why the scientists are not pulling their weight, scientists are wondering if the government really means what it says about technological self-reliance.

From a different standpoint, as Rosenberg (1990: 150) draws our attention to the activities of CSIR, it lacked appropriate effective mechanisms to articulate industrial needs and demands. As he observes:

> Its [CSIR] research activities were at times effectively insulated from information about the needs of the public and private sector firms that would be the ultimate users of their output . . . . Studies showed that most projects tended to be initiated by scientists themselves and that users of technologies generated by CSIR labs tended to be confined to firms situated in close geographical proximity. A related problem was that work on these technologies was terminated at the prototype stage.

Perhaps, the kind of attention the CSIR has drawn from various quarters, but particularly from an economic historian of Rosenberg's stature, is not unrelated to the fact that the organization in its existence for over four decades produced over 2,000 processes and technologies, both of small and medium range. But as the studies indicate, only a quarter of these found their way into some industrial consumption while a major portion of them still remain unexploited in the shelves of NRDC (see Alam and Langrish, 1984).

Another study by NISTADS (1989) undertaken in twelve leading national laboratories of India, which included some CSIR laboratories, confirms the views of Rosenberg to a large extent. For a scientific research force of 2,744 scientists, this study identified only twenty collaborative joint projects with industry and only twelve patent applications were filed. What is also revealing is the low degree of mobility of personnel between research institutions and industry. Out of 2,744 scientists, only 54 (1.9 per cent) visited the industry for research or consultation for the year 1988. This study also highlights the problem of linkages between research institutions and industry by way of administrative and organizational mechanisms. As this study (ibid.: 24) notes:

> there is [a] notable absence of industry personnel on advisory boards and selection panels of research institutions. Industry personnel invited for lectures or conferences to research institutions are rare. Some representation of scientists from research institutions on the selection committees and advisory boards of industrial concerns is there, even though the numbers are not large.

In the Indian context, a related feature is also the factor of weak linkages between full-time research institutions and the university sector as shown by the NISTADS (1989) study. R&D support for the university sector which remained at a low level of 7 per cent prevented many potential laboratory linkages which are significant for the 'upstream' R&D support of new technologies. There are however some notable exceptions, as in the case of molecular biology and biotechnology. Within the perspective of science agencies, the policies on science led to the isolation between the defence science agency, DRDO (which has about thirty-five national laboratories), and the industrial research of CSIR over the last three decades. Even the non-strategic component of defence science in electronics, food research and material sciences, among other areas, did not have collaborative links with the civilian R&D sector, though there were some sponsorships for research projects. For instance, in a small city like Mysore, the DRDO and CSIR maintain two large food research laboratories but they remain in relative isolation of each other.

The weak industrial orientation of national research laboratories is also indicated in the inventive activity through patents. The R&D statistics indicate 96,927 S&T personnel working in various R&D organizations for the year 1988, but the number of patents sealed by Indians was less than 900 for the year 1990. In the same year, foreign inventors registered more than 1,800 patents in India.

The second feature which is responsible for the under-utilization of R&D capabilities in agencies such as CSIR is the wide range of problems across various disciplines undertaken within what seems limited financial resources. If we were to compare with the successful projects of industrial laboratories in industrialized countries such as Japan, USA or other West European countries, it will be revealed that a couple of such projects entail budgets equivalent to the entire budget of CSIR's thirty-five laboratories. The emergence of the private sector as the major 'stakeholder' of the R&D component in the industrialized countries eliminated the under-utilization of the R&D factor to a large extent. Unfortunately, such a development has not come about in developing countries such as India.

South Korea is, however, an exception. In the absence of this development, the relative share of public R&D allocation of CSIR over the last two decades has drastically reduced. CSIR commanded about 27 per cent of the total R&D budget in the 1960s, which was reduced to 9.6 per cent in the 1980s.[33] Between 1976 and 1990, the relative share of R&D by public and private enterprises relatively stagnated when adjusted for inflation.

The third feature responsible for the under-utilization of R&D capabilities relates partly to the bureaucratic practices prevailing in S&T organization, including at the science agency and laboratory levels, and partly to the lack of dynamism in S&T policy formulation and its implementation, particularly in relation to the changing economic scenario. Lall (1987) and Rosenberg (1990) have dealt in considerable detail the bureaucracy problem relating to S&T, which needs no repetition here. The relevant conclusions of these studies point to the way in which the heavily bureaucratic and unwieldy procedures in the government departments in science, economics, commerce and industry made the flow of new technological know-how from outside very difficult and tedious on the one hand, and laid unnecessary stumbling blocks for coordination between different actors in the S&T and market network for cross-flow of information on the other hand.

On the other issue of S&T policies, as argued elsewhere (see Krishna, 1993a), the Indian S&T policies for a long time leading into the 1990s stressed the 'input side' of the R&D spectrum based on linear models of innovation. Consequently, the diffusion end of the R&D spectrum was left to the 'natural' play of actors and agencies involved in R&D, industry and the market network. At the level of S&T policy implementation, with the exception of import-substitution in S&T, there was little effort in linking S&T policy formulations with those in the industrial and economic related departments with appropriate institutional mechanisms for monitoring. For example, the government allowed R&D tax incentives for industry which either invested in research locally or obtained local know-how. But the policies had no penal or legal mandatory mechanisms, as in the case of South Korea (see Hyung-Sup Choi, 1986), to effectively monitor the schemes of incentives and introduce new institutional schemes to expand the R&D base of the private and public sectors. A related problem in S&T organization and basic research funding was the lack of mechanisms for research accountability and evaluation systems for research predominantly funded by the public purse.

## Concluding Remarks

Within the existing perspectives of science and empires in the context of former colonies of Africa, Asia and Latin America, the growth of the Indian scientific community presents a typical case. National or independence movements to surmount the tentacles of colonialism and imperialism, in varying forms, have taken roots in almost all countries. But the typicality of the Indian case is that the intellectual struggle to fight colonial science policies and to create, for the first time, a systematic local institutional base for the constitution of what is known as the Indian scientific community became an integral part of the political movement for independence. In the social history of science, Basalla's idea of independent science emerging from the 'embryo' of the colonial model of science is highly questionable from a look at the developments in Indian science. On a different plane, the recent ideas of Lewis Peyenson to subjugate the local (that is, former colonies) histories to that of the Western imperial history of a 'civilizing mission' has no empirical or intellectual basis in the case of India (see also Palladino and Worboys, 1993). Furthermore, the emergence of a local institutional science base in India, which constituted the early scientific community, cannot be solely explained within the framework of the 'moving metropolis' model of MacLeod (1987). There is enough evidence to suggest that the Indian developments were taking place independent of the loosening of the imperial power structures which is central to MacLeod's analysis.

The legacy of national sentiment coupled with the urge to create an independent economic base played an important ideological role for the post-independence growth of S&T infrastructure. In this growth scenario, no less important was the part of Nehru's leadership and the factor of close alliance that evolved between the political leadership and a small group of scientific elite in the 1940s and 1950s. As this elite represented the science agencies under the auspices of the government, the locus of Indian science predominantly expanded and concentrated in the science agency sector rather than in the academic, university sector for four decades after 1947.

During these decades, India built up a relatively substantial S&T institutional base compared to the other Third World countries. As the quantitative studies indicate, India accounts for half of the total Third World scientific production measured in terms of papers and journals. The historical growth of science in India has been able to generate a modest 'ecological' impact of science by creating a network of national journals, science academies, scientific societies, appropriate niches for drawing political legitimacy, systems of scientific stratification and intellectual spaces for recurrently institutionalizing new fields of scientific research.

India no longer suffers from the problems of 'isolation of scientists' and foreign monetary dependence for carrying out research in some crucial areas of national and local importance, which glaringly persist in many small developing countries. India is not a 'metropolitan' scientific power, but at the same time the status of Indian science is far removed from the notions of 'peripheral science'. In the areas of nuclear, space, agriculture, medical, and to a lesser extent, industrial research sectors, the achievements of the Indian scientific community defy the notions of peripherality of

Indian science in vogue in scientometric literature. But this is not to say that all is well with Indian science.

The problems confronting Indian science are, however, of a different professional and practical dimension compared to many small developing countries. These relate to improving the peer reviewing systems in the national laboratories and in a vast number of journals; increasing the mobility and interaction between the university sector and national laboratories; creating social and professional conditions to enhance greater collaboration and interaction between groups in a similar speciality (molecular biology for example); devising new organizational innovations which will tackle the problems of bureaucracy and dysfunctional 'social hierarchies' which prevent autonomy, free exchange of ideas and constructive dissent; innovating new institutional mechanisms to improve the effectiveness of research groups and infusing a high degree of research accountability. A related issue which bothers Indian S&T in the 1990s is how to arrest the annual outflow of over a 1,000 of the best talented human resources—particularly the 'cream', which is about 15 to 20 per cent.

From the point of a practical dimension, the effectiveness of Indian R&D in relation to the development or conversion of existing R&D capacities to commercial opportunities assumes significance. Economic strategies of self-reliance and import-substitution (the roots of which can be traced back to the economic nationalism of the pre-1947 era) legitimated the proliferation of S&T institutional growth for almost four decades. The Indian experience, in varying ways, underlines the point of under-utilization of R&D capacity generated thus far. The degree of the level achieved in building indigenous R&D capacities is far outstripped by the dependence on foreign technological know-how which, in a large measure, indicates the low potentiality of the R&D structures to absorb and generate adequate technological changes and 'novel' technical innovations required for a competitive industrial base. S&T policy experience, in its various ramifications, illustrates serious limitations of the orientation which is mainly concentrated on the 'input side' of R&D, often stressing the linear model of innovation. Closely related to this feature is also the long standing orientation of policies which, in a large measure, viewed science as a consumption factor rather than an investment factor. The lack of adequate mandatory mechanisms to couple the S&T policy regime with those of the industry and economic policy regimes in a number of ways contributed to the under-utilization of Indian R&D. Further, as the head of CSIR recently observed:[34]

> A sense of isolation continues to prevail in our working mode. This tendency has to change and we must devise new means and ways to work in close proximity and partnerships with the user industry clients and the relevant university sector. Towards this end, there is an urgent

> need to design [an] appropriate framework with practical mechanisms for S&T networking between science, technology, industry and the market locale . . . there is a need to dynamically restructure S&T policy instruments in alignment with the economic regimes (Krishna, 1993b: vi, vii).

In the present context of the ongoing economic reforms of liberalization and privatization, the effectiveness of the Indian scientific community greatly depends on the extent to which the networking in S&T, industry and market locales is accomplished. In an effort to optimize the existing infrastructure and infuse a greater degree of commercialization of research, the existing science agency structures demand new institutional innovations. Unnecessary boundaries between defence science and civilian R&D call for a thorough revision so as to bring the former within the orbit of S&T networking to facilitate unhindered mobility and linkages between the actors and agencies of the various components of the overall S&T system.

There are, however, some important S&T related issues which are not dealt with in this paper. As many developing countries, India is a country of composite cultures embedded in a complex matrix of socio-economic pluralism. In this perspective, the science and society, technology and culture, and rural and urban divide have time and again challenged the 'trickle-down theories' of modernization which assumed a smooth transformation out of S&T induced industrial growth. The rising religious and fundamentalist forces of many shades in the past decade have also increasingly challenged the rational and scientific–secular traditions of Indian civilization. The task of tackling a high proportion of illiteracy in the population and the simultaneous task of spreading scientific literacy pose additional challenges, both to the scientific community and the social order within which it could effectively operate. It is here that 'new' social and institutional innovations demand as much attention as 'new' techno-economic strategies for S&T policies.

## Notes

**Acknowledgements**: I am grateful to NISTADS/CSIR for granting my sabbatical during 1993–1994. I also wish to express my sense of gratitude to Maison des Sciences de l'Homme and ORSTOM (Science, Technology and Development Unit), Paris, for inviting me as visiting professor and visiting scientist, respectively, during my sabbatical period. I thank my collaborators, Dr. Roland Waast and Dr. Jacques Gaillard of ORSTOM for their co-operation and help, without which the writing of this chapter would not have been so smooth. The views expressed in this chapter are entirely mine and not of any organization.

1. Much of the discussion in this section is based on and drawn from two other papers (see Krishna, 1991, 1992).
2. In several ways the notion of colonial science directly implies a boundary orientation. As will be argued in this paper, the emergence of an Indian scientific community by the turn of the present century was due primarily to the efforts of the local Indian intelligentsia.

Given the geographical confinement of the colonial science concept, it will be erroneous, as Basalla (1967) thinks, to consider the growth of an independent, national science community as having emerged from the 'embryo' of colonial science in the specific case of India.

3. The Trigonometrical Survey of the Peninsula of India was established in 1800 (renamed the Survey of India in 1878); the Geological Survey of India was founded in 1851; the Calcutta Botanical Gardens (later renamed the Royal Botanic Gardens) led to the creation of the Botanical Survey of India in 1889; the office of the Inspector General of the Fisheries in India and Burma was created in 1870; the Archaeological Department was founded in 1862; the hydrographic surveys under the Indian navy department from 1832 led to the establishment of Indian Marine Survey Department in 1874; the establishment of the Indian Museum in 1866 led to a series of collection surveys in zoology and anthropology which formed the basis for the creation of the Zoological Survey of India in 1916; the office of the Inspector General of Forests and Forest Research was formalized in 1906; and in the area of medical research, investigations began on tropical diseases from 1869 which led to the creation of a formal department in 1906 and later the Indian Research Fund Association was created in 1910.
4. The main goals of the scientific enterprises were largely governed by imperial economic interests. For instance, as the biography of P.N. Bose (see Bagal, 1955) and the detailed reference to the development of the steel industry in India before the First World War in Headrick (1988) demonstrate, the Geological Survey of India (the flagship of colonial enterprises) grossly underplayed the development of the steel industry and related technical research.
5. As MacLeod's (1975) key paper demonstrates, a different mould of intra-British struggle was waged by the colonial science administration (Board of Scientific Advice) and by other individual scientists with the London administration. Their purpose was, however, not to promote advancement of science and its professionalization but was related to the issues of power sharing and enhancement of budgets for the colonial enterprises.
6. Independent of the government, with a modest collection of Rs. 61,000, Sircar pleaded that 'we should endeavour to carry on the work with our own efforts, unaided by the government. I want it to be entirely under our management and control. I want it to be solely native and purely national' (IACS, 1976: 9). IACS created seven research and teaching sections in general physics, physiology, astronomy, systematic botany, zoology, chemistry and geology. Till the turn of the century, the main contribution of IACS was the propagation of national relevance in the cultivation and promotion of science.
7. In 1903 and 1905, Viceroy Curzon's attempt to control technical education and exclude advanced research from its definition evoked sharp reactions from the protagonists of national education. The Dawn Society was transformed into the National Council of Education (NCE) in 1906 with a membership of ninety-six to organize a parallel structure of scientific and technical education 'on national lines under national control' (NCE, 1956: 3). These efforts led to the creation of the Bengal Technical Institute and the Bengal National College, which formed the basis for the present day Jadavpur University and the University College of Science and Technology, Calcutta University (see also Sarkar, 1977).
8. In the Bengal region, for which some authentic data is available, the private aid for education was 54 per cent of the total expenditure for Bengal in 1879–1880, which was increased to 56 per cent (Bengal Administration Report, 1880–1881, p. 53, quoted in Kumar, 1986). For a detailed study of Kala Bhavan from 1890 to 1910, see Raina and Habib (1992).
9. The establishment of the Indian Institute of Science (IISc) in 1909 through the efforts of Indian industrialist, Jamsetji Tata and the princely contribution of land by the Mysore State; the efforts of Father Lafont at St. Xavier's College for the promotion of higher research; P.C. Ray and J.C. Bose at the Presidency College (the nucleus of the Hindu College established in 1817 formed the basis for this college) after 1885 for the promotion

of chemical and biological research; the efforts of J.C. Bose for the creation of the Bose Research Institute (BRI) in 1917 which specialized in the field of plant physiology; and the efforts of Tata and P.C. Ray by 1915 for the development of industrial research in steel and chemicals, laid firm institutional foundations for systematic higher research by the 1920s.

10. Some of the societies dealing with science and society included the Aligarh Scientific Society (1864), Bihar Scientific Society (1868), Punjab Science Institute (1886), the Dawn Society (1904), ISCA (1914), and the Association of Scientific and Industrial Organization (1904). Between 1868 and 1900 there were ten popular science magazines and forty-seven technology related magazines in Bengal alone.
11. On radio receivers, Partrick Geddes, biographer of J.C. Bose, accords him priority over Marconi.
12. Referring to the 126 papers contributed to various societies and journals such as the *Chemical Society* (London), *Journal of the American Chemical Society*, and others, *Nature* in its 23 March 1916 issue observed that, 'some of these papers are of very considerable value and interest, and indicate enthusiastic work on the part of this newly created school' (Ray, 1958: 150).
13. The scientific meetings of the IACS from 1917 provided an important professional forum for discussing advanced research in physics, geology, biology and chemistry. Reviewing the work of physics between 1907 and 1917 in one of the meetings, Raman observed that, 'a real school of physics has grown up in Calcutta . . . which will not compare very unfavourably with those in European and American universities' (IACS, 1976: 30). Raman also referred to the list of twenty original papers of S.K. Banerjee, S.K. Mitra and M.N. Saha. Around 1918, the Calcutta Physical Society was established under the auspices of Calcutta University. K.S. Krishnan, the first director of the National Physical Laboratory, joined Raman after 1920, and the advances in optics were carried out which enabled this team to achieve world recognition for the finding of the 'Raman Effect'.
14. After the establishment of Banaras Hindu University in 1918 by the Indian political leader, M.M. Malaviya, Ganesh Prasad founded the Banaras Mathematical Society. Prasad's main contribution in applied maths included the publication 'Constitution of Matter and Analytical Theories of Heat' by the Royal Society of Sciences of Gottingen (1903) and the book on the Fourier Series dealing with the theory of real variables in the 1920s.
15. Besides ISCA and IACS others included the Indian Mathematical Society (1907), Calcutta Mathematical Society (1908), Indian Botanical Society (1920), Institution of Engineers, India (1920), Anthropological Society (1920), Indian Psyco-Analytical Society (1922), Indian Chemical Society (1924), Geological, Mining and Metallurgical Society of India (1924), Indian Psychological Association (1924), Society of Biological Chemists, Bangalore (1931), Indian Physical Society (1934), Indian Physiological Society (1935), Indian Society of Soil Science (1934), Academy of Sciences, Allahabad (1930), Calcutta Geographical Society (1933), Indian Academy of Sciences (1934), and Indian National Science Academy (1935).
16. In fact, there existed an Advisory Committee for Coordinating Scientific Work (ACCSW) which was set up in 1948. Nehru was the chairman and Bhatnagar was the secretary. ACCSW operated till 1956 when it was replaced by the Scientific Advisory Committee to the Cabinet (SACC). This Committee was also chaired by Nehru and other members included Bhabha, Kothari and others who were already close to the 'power corridors'.
17. Vikram Sarabhai, the head of the Atomic Energy Commission in the 1970s posed the question 'whether science in India is poised to create national wealth', in one of the meetings of a science advisory body. The plan to develop indigenous battle tanks, overt displays of nuclear potential in the 1970s, launching satellites designed by the Indian Space Research Organization (ISRO) and the relative success of Green Revolution concept are examples of the post-1970s period which legitimated S&T in policy discourse in India.

18. However, this development may be said to have come in after the Nehru era. Mrs. Gandhi, addressing the Third Conference of Scientists, Technologists and Educationists during 28–30 November 1970, observed that 'it is rather disturbing to find that the leaders of this community, who should guide the government, themselves seem to look towards the government bodies most of the time' (from the unpublished proceedings of the Conference).
19. Edward Shills in the late 1960s calculated research expenditure by academic scientists as Rs. 6,000 per annum per scientist, whereas the figure for ICMR was Rs. 16,000, for CSIR Rs. 45,000 and for DAE Rs. 72,000.
20. In fact, Bhabha directed his criticism at CSIR but perhaps he very well knew that the same criticism was in a large measure valid for his DAE.
21. An important study dealing with the 'in between' situation is that of Chatelin and Arvanitis (1988). Here, however, the intention is not to specifically further the concept of 'in between', but to question the periphery thesis of scientometricians dealing with India.
22. Much of this qualitative and quantitative research is predominantly based on the Science Citation Index (SCI) analysis of the Institute of Scientific Information (ISI) of Eugene Garfield. The main conclusions of these writings, which propagate the periphery 'thesis', are drawn from the analysis of comparative impact factors which place the status of Indian scientific publications and Indian journals in the lowest rank of countries. For example, the observed citation rate per publication in all scientific fields shown by Arunachalam and Manorama (1989) and others for USA is 3.82, for France is 2.32, Netherlands 3.26, Thailand 1.01, Philippines 1.03 and India 0.80. Curiously, USSR is shown to have 0.62.
23. The creation of the Institute of Andean Biology in 1931 at San Marcos University professionlized the field, which flourished with many world class research contributions during the 1930s and 1950s.
24. Given the under-representation of Indian journals in the SCI, which leaves out about 97 per cent of the 440 journals covered elsewhere, the characterization of Indian science as peripheral appears to be an erroneous view. From a different standpoint of national R&D expenditure, only 8 to 10 per cent of the research is said to be described as basic-oriented research while the rest of about 90 per cent is said to be applied or development-oriented research governed by national economic goals. As a scientist from a CSIR laboratory working on toxicological research reflected, 'water and chemical pollution research in Kanpur and Lucknow may be of very low status in the eyes of international science but the results of such research might, if implemented properly, benefit the health of few lakhs or even few million people' (personal interview, January 1993).
25. From the informal discussions had with Dr. Bachawat and Dr. P.M. Bhargava during October–November 1992 at the tenth anniversary celebrations of the Molecular Biology Centre, Banaras Hindu University.
26. From the perspective of 'brain gain', it may be pointed out that during the decade beginning 1980 several advanced research groups in molecular biology, biotechnology, laser, superconductivity, telecommunications, advanced computing and telematics, and microelectronics were established and are now mostly led by Indian scientists who returned from the USA and Europe. No detailed study is available but the figure by conservative estimates may be put at around 1,000 scientists.
27. Much of this information and data are drawn from Ramachandran (1991) who was the head of the DBT for almost one decade.
28. See Government of India, *Draft Fifth Plan*, Vol. 1, para. 5.26, p. 135.
29. Before the CSIR food process transferred to AMUL, this cooperative was based on ten villages as members in the 1950s. Each village is a member which represents 200 to 1,000 family units. After the commercialization of the CSIR process in the cooperative, it expanded to cover, by the 1980s, about 1,000 members. This success is generally known as the 'white revolution' which has now spread to nineteen other Indian states.

30. These fifty-eight projects led to the commercialization of thirty-three chemicals and drugs manufactured by the chemical industry solely due to the policies of the government which either restricted foreign collaboration (as in twenty cases) or banned imports of chemicals and drugs (as in thirteen cases). These included important drugs such as edosulfan, acetanilide and butyl titanate. Apart from these thirty-three cases there are drugs, such as vitamin B6, in the fifty-eight commercialized projects which are produced by Indian-based firms and which compete in the multinational dominated market of the pharmaceutical industry. Another notable case is the pesticide endosulfan production which led to the expansion of the drug industry. The new plant for the production of this pesticide by the Hindustan Insecticides Ltd. (originally intended to be based on foreign technology), switched over to the National Chemical Laboratory process after the tests completed in the laboratory's pilot plant in the 1970s.
31. The state-owned fertilizer R&D, and design and consultancy organizations developed capabilities to launch 400 to 600 tonnes per day fertilizer plants. The R&D unit of the Bharat Heavy Electricals Ltd. (BHEL) achieved capabilities to develop 50 to 250 Mw turbo generators for hydroelectricity projects. As a spin-off from the atomic energy establishment, the DOE was set up which designed and developed a highly sophisticated twin-computer controlled system for the first experimental fast-breeder test reactor—all these by the late 1970s. There is a detailed account of this scenario in Parthasarathi (1979) which does not need repetition here.
32. As the 'Swaraj' tractor case and other episodes in the power and fertilizer industry demonstrate, there is no guarantee that the technology developed in the government laboratories will find its way into production in the government-owned public sector companies.
33. CSIR's own budget for the decade between 1980 and 1991 in fact stagnated when adjusted for inflation.
34. From S.K. Joshi's 'Preface' to the volume on *S.S. Bhatnagar on Science, Technology and Development: 1938–54* (see Krishna, 1993b).

## References


**Ahmad, A.** (1985). 'Politics of Science Policy in India'. *Science and Public Policy*, 12(5), 234–40.

**Arunachalam, S.** and **K. Manorama** (1988). 'How do Journals on the Periphery Compare with Mainstream Scientific Journals'. *Scientometrics*, 14(1–2), 83–95.

——— (1989). 'Are Citation based Quantitative Techniques Adequate for Testing Science in the Periphery'. *Scientometrics*, 15 (5–6), 383–408.

**Alam, G.** and **J. Langrish** (1984). 'Government Research and its Utilization by Industry'. *Research Policy*, 13 (1), 55–61.

**Aurora, G.S.** and **W. Morehouse** (1974). 'The Dilemma of Technological Choice in India: The Case of the Small Tractor'. *Minerva*, 12 (4), 433–58.

**Balram, P.** and **S. Ramaseshan** (1991). 'Coming of Age in Biotechnology'. *Current Science*, 60 (9–10), 25 May.

**Basalla, G.** (1967). 'The Spread of Western Science'. *Science*, 156 (5 May), 3775.

**Bagal, J.C.** (1955). *Pramatha Nath Bose*. New Delhi.

**Bhabha, H.J.** (1966). 'Science and the Problems of Development'. *Science*, 4 February, 541–48.

**Bhattacharya, D.P., R. Chakravarty** and **R.D. Roy** (1989). 'A Survey of Bengali Writings on Science and Technology'. *Indian Journal of History of Science*, 24 (1), 8–66.

**Bhargava, P.M.** and **C. Chakravarty** (1991). 'The Role and Present Status of Biotechnology in India'. *Current Science*, 60 (9–10), 513–17.

**Braun, T., W. Glanzel** and **A. Schubert** (1988a). 'World Flash on Basic Research, 1981–85'. *Scientometrics*, 13 (5–6), 181–88.
——— (1988b). 'World Flash on Basic Research, 1981–85'. *Scientometrics*, 14 (1–2), 9–15.
——— (1988c). 'World Flash on Basic Research, 1981–85'. *Scientometrics*, 14 (5–6), 365–82.
**Burma, D.P.** (1992). 'Development of Molecular Biology in India'. *Proceedings of Indian National Science Academy*, 58 (5), 217–26.
**Chaudhury, S.** (1986). 'Technological Innovation in a Research Laboratory in India: A Case Study'. *Research Policy*, 15 (2), 89–103.
**Chatelin, Y.** and **R. Arvanitis** (1989). 'Between Centres and Peripheries: The Rise of A New Scientific Community'. *Scientometrics*, 17 (5–6), 437–52.
**Cueto, M.** (1989). 'Andean Biology in Peru: Scientific Styles on the Periphery'. *ISIS*, 80 (304), 640–50.
**Eisemon, T.** (1982). *The Science Profession in the Third World*. New York: Praeger.
**Eisemon, T.** and **C. Davis** (1989). 'Mainstream and Non-Mainstream Scientific Literature in Four Peripheral Asian Scientific Communities'. *Scientometrics*, 15 (3–4), 215–39.
**Fleming, D.** (1964). 'Science in Australia, Canada and the United States: Some Comparative Remarks'. *Proceedings of the Tenth International Congress of History of Science*. Itacha: The Secretariat, International Congress of History of Science.
**Gaillard, J.** (1991). *Scientists in the Third World*. Lexington, Kentucky: The University Press of Kentucky.
**Headrick, D.R.** (1981). *The Tools of Empire*. New York: Oxford University Press.
———. (1988). *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850–1940*. New York: Oxford University Press.
**Hyung-Sup, Choi** (1986). 'Science and Technology Policies for Industrialisation of Developing Countries'. *Technological Forecasting and Social Change*, 29 (3), 225–39.
**IACS** (1976). *A Century*. (Centenary Volume). Calcutta: IACS.
**Inkster, I.** (1985). 'Scientific Enterprise and the Colonial Model: Observations on Australian Experience in Historical Context'. *Social Studies of Science*, 15 (4), 677–706.
**Krishna, V.V.** (1987). 'Organisation of Science and Orientations of Scientists in CSIR (India) and CSIRO (Australia) Institutions'. Unpublished PhD Thesis. The University of Wollongong, Wollongong, NSW, Australia.
———. (1991). 'The Emergence of Indian Scientific Community'. *Sociological Bulletin—Journal of Indian Sociological Society*, 40 (1–2), 89–107.
———. (1992). 'Colonial "Model" and the Emergence of National Science in India, 1876–1920', in P. Petitjean, C. Jami and A.M. Moulin (eds.). *Sciences and Empires: Historical Studies about Scientific Development and European Expansion*. Dodrecht, The Netherlands: Kluwer Academic Publishers.
———. (1993a). 'Science Policies to Innovation Strategies: "Local" Networking and Coping with Internationalism in the Developing Country Context'. *Knowlege and Policy*, 6 (3–4), 134–57.
———. (1993b). *S.S. Bhatnagar on Science, Technology and Development, 1938–54*. New Delhi: Wiley Eastern Ltd.
**Krishnan, C.N.** and **B. Viswanathan** (1987). 'The Performance of Modern Science and Technology in India: The Case of S&T Journals'. *PPST Bulletin*, 11 (1), 1–19.
**Kumar, D.** (1983). 'Racial Discrimination in Science in 19th Century India'. *Indian Economic and Social History Review*, 19 (1), 63–82.
———. (1986). 'Science Policy of the Raj: 1857–1905'. PhD Thesis. Delhi: Delhi University.
**Lall, S.** (1987). *Learning to Industrialise*. London: Macmillan.
**Long, F.A.** (1979). 'Science and Technology in India: Their Role in National Development', in J.W. Mellor (ed.). *India: A Rising Middle Power*. Boulder: Westview Press.

**MacLeod, R.** (1975). 'Scientific Advice for British India: Imperial Perceptions and Administrative Goals'. *Modern Asian Studies*, 9 (3), 343–84.

———. (1987). 'On Visiting the Moving Metropolis: Reflections on the Architecture of Imperial Science', in N. Renigold and W. Rosenberg (eds.). *Scientific Colonialism: A Cross-Cultural Comparison*. Washington: Smithsonian Institution Press.

**Mahalanobis, P.C.** (1974). 'Recent Developments in the Organisation of Science in India', in A. Rahman and K.D. Sharma (eds.). *Science Policy Studies*. Bombay: Somaiya Publications.

**Morehouse, W.** (1976). 'Professional Estates and Political Actors: The Case of the Indian Scientific Community', in W. Morehouse (ed.). *Science and Technology in India*. New Delhi: Vikas Publishing House Pvt Ltd.

NCST (1973). *An Approach to the S&T Plan 1974–79*. New Delhi: DST.

NCE (1956). *National Council of Education, 1906–56*. (Golden Jubilee Volume.) Calcutta: NCE.

NISTADS (1989). *A Study of Linkages of Research Institutions with Academic Institutions and Industrial Organisations*. New Delhi: NISTADS.

**Padmanabhan, G.** (1991). 'An Assessment of Current Indian Scene in Biotechnology'. *Current Science*, 60 (9–10), 510–13.

**Pal, B.P.** (1977). 'Science and Agriculture', in B.R. Nanda (ed.). *Science and Technology*. New Delhi: Vikas Publishing House Pvt Ltd.

**Palladino, P.** and **M. Worboys** (1993). 'Science and Imperialism'. *ISIS*, 84 (1), 91–102.

**Parthasarathi, A.** (1974). 'Appearance and Reality in Two Decades of Science Policy', in A. Rahman and K.D. Sharma (eds.). *Science Policy Studies*. Bombay: Somaiya Publications.

———. (1979). 'India's Efforts to Build an Autonomous Capacity in Science and Technology for Development'. *Development Dialogue*, 1 (1), 46–59.

**Prasad, B.** (ed.) (1938). *The Progress of Science in India During the Past Twenty Five Years*. Calcutta: Indian Association for the Cultivation of Science.

**Raina, D.** and **S. Irfan Habib** (1992). 'Technical Content and Social Content: Locating Technical Institutes—The First Two Decades in the History of the Kala Bhavan, Baroda (1890–1910)', in P. Petitjean, C. Jami and A.M. Moulin (eds.) (1992). *Sciences and Empires: Historical Studies about Scientific Development and European Expansion*. Dodrecht, Netherlands: Kluwer Academic Publishers.

**Ramachandran, G.** (1991). 'Government Funding and Support for the DBT'. *Current Science*, 60 (9–10), 518–23.

**Ramamurthi, P.** (1978). *Stop BHEL's Dangerous Trucks with Siemens: An Investigative Analysis*. New Delhi: Centre for Indian Trade Unions (CITU).

**Rahman, A.** (1983). *Science Policy in India*. New Delhi: NISTADS.

**Ray, P.C.** (1902). *The History of Hindu Chemistry: From Earliest Time to the Middle of Sixteenth Century A.D.* 2 vols. Calcutta: Bengal Chemicals and Pharmaceuticals Company.

———. (1921). 'Presidential Address to the Seventh ISCA, 1920'. *Proceedings of the Asiatic Society of Bengal (New Series)*. Calcutta: Asiatic Society of Bengal.

———. (1958). *Autobiography of a Bengali Chemist*. Calcutta: Orient Book Company.

**Rosenberg, N.** (1990). 'Science and Technology Policy for the Asian NIC's: Lessons from Economic History', in R.E. Evenson and G. Ranis (eds.). *Science and Technology Lessons for Development Policy*. London: Intermediate Technology Publications.

**Sandhya, G.D.** and **A. Jain** (1992). 'An Ex-Post Evaluation of the Impact of Import-Substitution Strategy on Industrial Civil Research in India'. *Working Report-1992*. New Delhi: NISTADS.

**Sarkar, B.K.** (1918). *Hindu Achievements in Exact Sciences*. New York.

**Sarkar, S.** (1977). *The Swadeshi Movement in Bengal, 1903–1908*. New Delhi: Peoples Publishing House.

**Sen, S.N.** (1954). *Professor Meghnad Saha: His Life, Work and Philosophy*. Calcutta: M.N. Saha 60th Birthday Committee.

**Sen, B.K.** and **V.V. Lakshmi** (1992). 'Indian Periodicals in the Citation Index'. *Scientometrics*, 23 (2), 291–318.

**Shills, E.** (1969). 'The Academic Profession in India'. *Minerva*, 7 (3), 345–76.

**Stafford, R.A.** (1990). 'Annexing the Landscapes of the Past in British Imperial Geology in the 19th Century', in John M. Mackenzie (ed.). *Imperialism and the Natural World*. Manchester: Manchester University Press.

**Valluri, S.R.** (1993). 'CSIR and Technological Self-Reliance'. *Economic and Political Weekly*, 28 (14), 3 April, 565–68.

**Visvanathan, S.** (1985). *Organising for Science: The Making of an Industrial Research Laboratory*. New Delhi: Oxford University Press.

**Worboys, M.** (1979). 'Science and British Colonial Imperialism, 1890–1940'. Unpublished PhD Thesis. University of Sussex, Sussex.

# 10 The Thai Scientific Community: Reforms in the NIC of Time?

**Charles H. Davis, Jacques Gaillard** and
**Thomas Owen Eisemon**

Thailand, which means 'the Land of the Free', has maintained its political independence since the founding of the first Thai-speaking states eight centuries ago by resisting incursions from neighbouring states and, more recently, by fending off the Western imperial powers that laid claim to surrounding regions. In the post-War period, Thailand profited from its geopolitical situation, and its natural and cultural endowments to foster dizzying development, propelled by the highest national growth rates in the world in the late 1980s. This development has brought significant prosperity to many Thais and has raised the standards of living of a great many others, but at the cost of severe regional disparities, Bangkok's staggering congestion, and a variety of other disquieting social and environmental ills (Komin, 1989).

Cultural borrowers par excellence (Watson, 1989), the Thais have historically shown remarkable gifts for picking and choosing among various foreign institutional models, and adjusting and adapting them to suit their own purposes. The history of educational and scientific institutions in Thailand in the past century is one of a succession of foreign models—originally European, and more recently North American and Asian—that have been transplanted, retrofitted, infused with indigenous elements and experimented with.

However, new challenges to Thailand are raised by the rapid industrialization of the Pacific Rim and more generally by the global race to maintain economic competitiveness. Thailand aspires to become a Newly Industrializing Country (NIC) and much scholarly debate is taking place concerning whether or not Thailand is on the right track. Industrialization in the late twentieth century and success in global markets are underpinned by the capacity of a society to mobilize S&T for economic and social purposes. Although the growth rates, the patterns of investment, export and consumption, and the Thai cultural outlook all suggest that the country is poised to take its place among the world's developed economies, observers of the Thai system of industrial innovation are voicing alarm. Growth has come so quickly and so easily, they say, that the whole edifice of modern industrial Thailand is built upon a too-shallow foundation of scientific and technical skills. Thai S&T policy makers consider that extraordinary measures must be taken in the coming years to find ways to broaden and deepen the country's scientific and technical bases in the economic sector.

The problem of the sustainability of Thailand's industrial development is compounded by the lingering difficulty experienced by the Thai research community in reproducing itself (Gaillard, 1990). Despite the impressive development of the Thai scientific community during the 1960s and 1970s, Thailand is still unable to endogenously produce the cadre of high level scientific manpower that it needs in its research system. As in most developing countries, private sector R&D activities are very limited and mainstream scientific outputs are concentrated in the oldest metropolitan universities (Yuthavong, 1986). While Thailand is a regional leader in the quality and quantity of tertiary education, it lags in terms of secondary education. Furthermore, demand for technically skilled human resources has outstripped the ability of the education system to meet it and huge bottlenecks have developed in the supply of engineers. These bottlenecks are hindering Thailand's capacity to move up the technology ladder.

Since the late 1970s, Thailand has made relatively consistent and serious efforts to design and implement policies for S&T. Many studies of the Thai innovation system have been undertaken in recent years, often with the support of bilateral and multilateral donor agencies who are keenly interested in taking the scientific and technical pulse of this strategic country. As a result, Thai policy makers and researchers have a relatively good fix on the problems of scientific and technical development in Thailand. Many of Thailand's problems are those of a less developed country; these include problems of public health, poverty, regional disparity and environmental degradation. However, Thailand differs from most developing countries in one key respect. While many less developed countries are attempting to use S&T to move their national economies into a growth dynamic to generate income, this is not the problem in Thailand. The problem is that rapid economic growth has been driven by factors that are only marginally related to Thailand's scientific and technical capabilities. Consequently, there has been relatively little reinvestment of private wealth into the Thai S&T system except in the form of purchased capital equipment which is usually foreign. It is only in the recent past that the manufacturing sector has begun to express a demand for locally produced inputs, mainly in the form of technical personnel and also infrequently for technical support services.

Thailand is eager to join the ranks of the four Asian Tigers (Korea, Hong Kong, Taiwan and Singapore). However, the dynamics of industrialization in these first generation Pacific Rim late industrializers were undoubtedly very different from those that can be anticipated in Thailand (see Lall, 1990). Presently a plausible candidate to be the next Asian Tiger, Thailand must worry that the window of opportunity created by the global economic order in the past four decades (which have been relatively good to Thailand) will close before Thailand's innovation system is vigorous enough to drive the economy's growth. Vietnam, in particular, with its highly skilled work force and vast agricultural potential is viewed as a likely contender for Thailand's present economic niche. All agree the time for Thailand to move up the technology ladder has come. Although some observers advocate that Thailand should attempt to move into certain relatively mature heavy industries such as chemicals and automobiles, others argue that Thailand explore new models of industrialization based on biotechnologies (see for example Ichikawa et al., 1991). Whatever the strategy, to be effective it must put in place an array of institutions and policies to broaden and deepen Thailand's indigenous national technological capabilities.

It would be misleading to pretend to find consistently simple and direct relationships between endogenous scientific capacities, and processes of economic and social change. Any country able to exploit its own scientific capacity has developed an indigenous innovation system, which consists largely of actors outside the research system. Technology innovation systems are more complex than scientific communities (Clark, 1987). Most technology innovation systems include disparate actors of heterogeneous status: large, small, foreign and domestic firms; public and private laboratories; research, education and training institutions; financial bodies; and planning, policy making or programme agencies from each governmental level.

An in-depth examination of the emergence, structuring and social linkages of the Thai scientific community is not possible here. We limit ourselves to a sketch of the factors that are transforming the Thai scientific community, focusing on the emergence and differentiation of the higher education system, and the goals and institutions of Thai S&T policy.

## The Economic and Social Context of Investments in Science in Thailand

Thailand's interest in S&T is a response to the critical problem of sustaining the development of an economy in which growth in the past three decades has become concentrated in massive exports of low-wage manufactured goods. The Thai manufacturing sector grew at an average rate of 8.3 per cent in the period 1975–1985; in 1987, 1988 and 1989 the annual increases were 13.3 per cent, 16.8 per cent and 17 per cent respectively (*Bangkok Post*, 1990). Exported industrial goods include textiles, canned foods, assembled automotive vehicles, assembled electronics devices, ceramics, and some rubber and plastic products. In 1987, the top ten Thai manufactured exports in terms of revealed comparative advantage were tin, undergarments, leather, gold and silver jewellery, women's outerwear, precious and semi-precious stones, wood, men's outerwear, textiles and knitted undergarments (Dahlman et al., 1990; Appendix Table 2.1). The growth of the Thai manufacturing sector is attributable mainly to foreign direct investments, low-wage trainable labour, high rates of domestic protection, a stable macro-economic policy, a realistic exchange rate policy, export incentives and access to large markets in industrialized regions. The share of manufactured production in resource-based industries is decreasing and is increasing in labour-intensive industries. In science-based, scale-intensive or differentiated industries, no change in relative share has taken place (ibid.). Resource- and labour-intensive products present 75 per cent of Thailand's exports.

Agriculture still provided employment to about 67 per cent of the labour force, but it generated only 16 per cent of the GDP in 1988, declining from 27 per cent in 1975 (TDRI, 1990a: Tables 3 and 11). However, the value of agricultural goods and services tripled during this period, increasing by 22 per cent between 1987 and 1988. Agriculture's share of total exports dropped from almost half (46 per cent) of the exports in 1982 to a quarter (26 per cent) in 1990. Rice and rubber are still among the country's most important commodity exports. The value of these traditional exports still exceeds that of textile products. Export earnings for rice and rubber taken together are declining, although the decline is not as dramatic as for maize exports, whose value has fallen by half since 1985 (TDRI, 1990b: Table 6). The decline in the value of commodity agriculture exports reflects increased competition from other agricultural producers in the Asian region, poor prices and difficulties in securing access to markets in Europe and Japan.

The Thai model of economic development has had a particular kind of impact on national scientific and technological capacities. Thailand's industrial base remains very shallow and dependent on transfers of foreign investment and foreign technical inputs of all kinds. Only 0.17 per cent of GNP was spent on R&D from 1975 to 1987 (TDRI, 1989c), GERD/GNP ratios actually declined in the 1980s when the economy expanded rapidly and R&D expenditures failed to keep pace.[1] Most of Thai R&D is publicly financed and conducted in the public sector. Consequently, 'adaptive and innovative capabilities mainly reside in universities and government laboratories while operative capabilities, to the extent that they exist, reside in producing firms' (TDRI, 1989a: 2). Thailand's private sector conducts little R&D. Many studies of Thai technological capacities have been carried out by the Thailand Development Research Institute (TDRI), the Ministry of Science, Technology and Energy (MOSTE) and by foreign donors. In the aggregate, these studies reached similar conclusions: most firms in the modern sector have adequate ability to operate production technology but they 'are weak in searching for, acquiring, and adapting foreign technology. They are even weaker in developing their own technology' (Dahlman et al., 1990: 53).

In spite of these potentially serious structural shortcomings, Thailand's economic and social success is obvious to other less developed countries. This is because 'the Thais have demonstrated that it is possible to succeed without massive external assistance or the discovery of oil riches' (Nelson, 1991: 3).

## The Development of Science and Higher Education in Thailand: Brief Historical Background[2]

The Thai nation originated in the south of China. The invasions of the Mongol armies of Kublai Khan in the thirteenth century created migratory movements that led to cataclysmic changes in South-east Asia. Thai-speaking groups fled south, forming innumerable principalities in the central and northern parts of the region, chief among them the Sukothai Kingdom in what is now central Thailand. In the course of the following two centuries a major Thai-speaking regional empire emerged, the Kingdom of Ayudhya, supplanting the older Khmer Pagan empires (Wyatt, 1984). The Thai language was formalized and the Thai alphabet created.

Although Thai culture remains marked by its origins in China, Thailand adopted a Brahmanic system of justice and Therevada Buddhism as its state religion. Ayudhya secured itself against persistent conflict with the Burmese state and became an important international commercial centre, its ships trading from Korea to Persia. It was thus that by the sixteenth century the Kingdom of Ayudhya entertained diplomatic and commercial relations with foreign powers, including several European states—treaties were signed with Portugal in 1516 and Spain in 1598, and ambassadors were posted in Holland and England in the early seventeenth century. The reign of King Narai (1656–1688), under the influence of the Greek adventurer-turned-royal adviser Constantin Phaulkon, was marked by the development of closer relations with France and the exchange of ambassadors with Louis XIV. Through contact with European traders, missionaries and governments, a number of Western medical, commercial and military sciences and technologies were introduced, including a writing machine brought by a missionary (MOSTE, 1987a). But the Western powers' commercial intrigues and the religious activities of their missionaries led to a nationalist reaction at the death of King Narai, and relations with the West declined. When missionary activity was permitted again in the early nineteenth century, it was strictly regulated (Watson, 1989). From missionaries and traders Thais acquired skills in watchmaking, shipbuilding, mechanical engineering, physics and chemistry (MOSTE, 1987b).

The history of modern science in Thailand began in earnest with the arrival to the throne of King Mongkut (1851), recognized as the father of Thai science (*Thai Life*, 1985). King Mongkut was the fourth of the Chakri dynasty, established in 1782 with Bangkok as its capital. In the context of regional geopolitics dominated by French and British imperial rivalries, King Mongkut and his successor King Chulalongkorn (1868–1910) introduced important administrative, economic and social changes to Thailand while maintaining the country's independence (Muscat, 1966). Both recognized that their country could not sustain independence in the face of European imperialism without mastering and adapting the knowledge, the institutional models and the technologies generated by the West. A policy of modernization resulted during Chulalongkorn's reign; slavery and feudalism were abolished; modern public administration was established; railroads, telegraphs, telephones, electrical grids and urban water systems were constructed; and large-scale irrigation works were undertaken.

King Chulalongkorn was the first Thai monarch to travel to neighbouring countries as well as to Europe, which he visited twice. In 1890 he sent the first Thais, members of the royal family, to Europe (mainly to England) for education. Chulalongkorn's son Vajiravudh, who studied medicine at Oxford in England, continued the reforms of his father and grandfather. He founded Chulalongkorn University, the first Thai university, in 1916 in memory of his father.

## The Birth of the Thai Higher Education System: 1917–1943

Education in Thailand was at one time in the province of religion and was organized in close relation to monastic life. The educated elite was limited to men who served at the royal court and in monasteries. Very few women had access to education. The establishment of the civil service at the beginning of the century created new needs for educated personnel. These needs were at first filled by members of religious orders. Following the establishment of the Ministry of Education and the gradual development of the public school system, education moved away from the traditional *wat* ('temple') school. Elementary education was made mandatory by royal decree in 1921. In the decades following the promulgation of this decree, the education system had to confront numerous difficulties, the principal one being the scarcity of qualified teachers. To improve the level of instruction, numerous teacher training schools were opened (OPM, 1984).

It was also during the reign of King Chulalongkorn that the idea of establishing modern institutions of higher education emerged. The principle followed was that of establishing specialist institutions to provide civil servants to specific government departments, like the French Grandes Ecoles (Watson, 1991). Paetyakorn Medical School (1889), a law school (1897) and the Royal Pages School for future government administrators (1902) had already been established when King Vajiravudh, who had been exposed to European educational thinking during his study in England, proclaimed the Royal Pages School to become the Civil Service College in 1910. This school, intended for future members of the upper civil service, was to offer training in administration, foreign relations, agriculture, medicine, law, commerce and education. The Civil Service College was upgraded to university status in 1917. Paetyakorn Medical School and the Engineering School of Hor Wang, established in 1913, were attached to Chulalongkorn University, which at that time had four faculties: medicine, political science, engineering, and arts and science. A three-year programme of study led to a diploma. An agricultural training school was also established. Between 1923 and 1934, Chulalongkorn University received active support from the Rockefeller Foundation for the reform of medical education, the objective being to deliver a recognized doctor with a medical degree. The first Chulalongkorn University MD degrees were granted in 1930. In 1935, the first Chulalongkorn University Act was promulgated, establishing diplomas in medicine, arts, science and engineering, and the first Bachelor's of Science degrees were awarded in 1935, followed a few years later by the first Master's degrees.

Although no foreign advice was sought, the model of the Thai university system at this point was clearly European, with closed access, teaching organized by faculties, instructional programmes of specific lengths and government controlled (Watson, 1989). The results were that:

> as new universities were opened during the next forty years, they became associated with specific government ministries. As a result they were seen as 'finishing schools' or as 'professional training schools for government' rather than as communities of scholars engaged in research and the pursuit of truth. Moreover, all the new schools were situated in and around Bangkok, the capital. The effects of this . . . were to lead to an excessive dominance of key decision-making departments and of economic concentration in the capital, leaving much of the rest of the country scarcely affected until the 1960s (Watson, 1991: 71–72).

This model prevailed until the 1960s. Five specialized institutions, all of which eventually became universities, were opened on this model between 1933 and 1943. In 1933, the second Thai university, the University of Moral and Political Science, was created. Renamed Thammasat University in 1952, this university serviced the Ministry of Public Justice and the Department of Public Administration. A third university, which became Mahidol University in 1969, was created in 1942 from Chulalongkorn University's Faculty of Medicine and Departments of Pharmacy, Dentistry and Veterinary Sciences. The foundations of Thailand's well-known capabilities in bio-medical sciences were developed at Mahidol University, which serviced the Ministry of Public Health. Two other specialist institutes in agriculture and forestry provided training for the Ministry of Agriculture. They were merged in 1943 to establish the predecessor of Kasetsart University, Thailand's first agricultural university.

## The Expansion of Higher Education in Thailand: 1943–1992

The 1960s saw dramatic changes in Thailand's system of higher education. Rapid population growth and the development of elementary and secondary schooling created strong demands for higher education. Furthermore, concerns about the production of human resources for economic development provided a rationale for expanding access to higher education. Finally, the turbulence in neighbouring countries in the 1960s and 1970s strengthened the rationale for creating educational opportunities outside of Bangkok. In accordance with the government's wish to attenuate regional disparities and decentralize the educational system, a university was established in each of the three main less developed regions of the country. Thus, Chiang Mai University in the north was the first university to be established outside the national capital. Chiang Mai University was followed in 1965 by Khon Kaen University for the north-eastern region, and in 1968 by the Prince of Songkhla University for the southern region. These institutions were and are intended to be agents of development and modernization.

The regional universities were established on the same model as the previous generation of Bangkok universities, with closed access and rigorous selection procedures that favoured students of higher socio-economic status from Bangkok. Because only a few regional students could compete for places in regional universities, a quota system was established to provide access for the top 25 to 40 per cent of school-leavers in the region.

The creation of the regional universities and the recourse to quotas represent the first departure from the closed access model of higher education that had prevailed in Thailand. Watson (1989, 1991) identifies three other responses to the inadequacies of the early model: system diversification at the tertiary level, creation of open access institutions and privatization.

Diversification took place through the establishment of new, specialized public institutions. The National Institute of Development Administration (NIDA) was created in 1966 to provide postgraduate training in public and business administration, statistics, development economics and the English language. The Asian Institute of Technology (AIT), an international engineering and management school, was established in 1967. AIT and Chulalongkorn University's Sasin Business School, which is affiliated with the Wharton School, provide two of the rare international environments in higher education in Thailand. A Thai technical university, the King Mongkut Institute of Technology, was established in 1971 through the amalgamation and ugrading of several small Bangkok-area technical institutes. A similar procedure created Srinakharinvirot University in 1974 from existing colleges of education.

By 1970, only 30 per cent of eligible candidates could be accommodated in Thai institutions of higher learning (Watson, 1991). To satisfy the burgeoning demand for higher education, two open universities were created. Ramkamhaeng University, established in 1971, provides Sorbonne-style mass higher education in social science disciplines to any secondary school graduate with no entrance exams. By 1980, 546,000 students were enrolled at this university, many on a part-time basis, taking over a 1,000 courses. Ramkamhaeng University may be the largest university in the world. The second open university, Sukothai Thammathirat Open University (STOU), was created on the model of the British Open University. In contrast to Ramkamhaeng University, STOU uses distance education techniques to offer courses in the social sciences, business disciplines and other applied fields. In 1983, 110,000 students were enrolled at STOU, which caters mainly to working adults.

In 1987, there were fourteen 'closed enrolment' public institutions of higher education in Thailand, enrolling 96,500 undergraduates and 19,300 graduates (MUA, 1988: Table 7). Between 1983 to 1987, the massive enrolments in the open universities declined from 657,000 to 522,000 (ibid.: Table 7). This is attributable to the rise of private universities in Thailand. The Private Colleges Act, passed in 1969, recognized six private, tertiary, degree giving institutions. In 1988, there were twenty-five private universities and colleges, with a total enrolment of 52,700 students at the Bachelor's level (a doubling since 1980), 700 at the Master's level and 6,800 at the Associate level (ibid.: Table 18). Nine private institutions (Bangkok University, Assumption Business Administration College, Dhurakijpundit University, Payap University, Institute of Social Technology, Rangsit University, Siam Technics University, Sripatum University and the University of the Thai Chamber of Commerce) account for 93 per cent of the total student enrolment in private institutes. Many of the private institutions are very small; sometimes they have a religious affiliation and they usually offer courses in business, informatics and low-cost health disciplines.

Thus, at the end of the 1980s, about 20 per cent of Thai university students were in elite, government-supported, 'closed enrolment' universities. Another 70 per cent were in low-cost, open enrolment, public universities. And about 12 per cent were in high-cost, relatively selective, private universities. In terms of full-time equivalents, however, the relative shares are 39 per cent in the closed universities, 36 per cent in the open universities and 24 per cent in the private universities (Myers, 1991). Total enrolments in Thai higher education have stayed nearly constant over the past decade.

Overall, the greatest expansion in production of human resources has come in the number of students in the social sciences and humanities (including the arts, commerce, education and law). Agronomy attracts relatively few students. The fact that the most important and the oldest of the Thai universities specializing in agricultural sciences is situated in the outskirts of Bangkok is surely a factor in its ability to recruit students, many of whom come to Kasetsart University to study business administration, engineering, electronics and other fields that are relatively far removed from agriculture (USAID, 1988). Nearly half of Kasetsart's students are from the metropolitan region and have only limited interest in agriculture. Among those that do, few intend to work in professions directly related to agriculture after having obtained a degree. Interest in scientific professions (chemistry, biology, physics) declined in the latter half of the 1970s and has remained low (Manunapichu, 1981), although it picked up again in the mid-1980s. One of the main reasons for low interest is that science graduates have not easily found work. Most jobs for science graduates are in the teaching field, with few opportunities for promotion or for generating additional income to supplement inadequate salaries. This is not the case for graduates in the business, law, informatics, and more recently, engineering fields, where job openings have been relatively abundant in the public and private sectors. These are fields in which private institutions of higher education have positioned themselves. The demand for engineers is leading a number of Thai private universities to offer instruction in this area.[3]

In 1986, less than 10 per cent of the students in Thai universities and colleges (about 57,000 out of a total of 678,000) were studying scientific and technical subjects (MUA, 1988).[4] Production of Master's and doctoral students in scientific and technical fields was very low until recently (many postgraduate programmes were established in the 1980s) and remains concentrated in the medical and health sciences. In 1986, 218 doctorates or equivalent degrees were awarded, 188 of them in the medical and health sciences (ibid.: Table 11). The most common qualification of the academic staff at Thai universities is a Master's degree; the highest concentrations of doctorates are to be found at Chulalongkorn, Kasetsart and Mahidol Universities.

The policy of the Thai government has been to limit the growth of financial support to public universities to about 2 per cent per annum. One of the objectives of this policy, in addition to reducing the growth of the government's financial obligations to universities, is apparently to increase the relevance of the universities' work with respect to national development needs. The public universities are expected to generate the supplementary or alternative income that they need. At the same time, however, the university system has remained part of the public sector, constraining universities' latitude with respect to tuition fees and salaries.

In 1992, legislation was introduced to 'privatize' the public universities. The nomenclature is misleading, because under the new legislation the universities would still remain public institutions, eligible for public funds, but would acquire greater autonomy with respect to their own curricula and financial decisions, including tuition fees, tenure, salaries and involvement in income-generating activities. This could be another watershed in the history of Thai scientific institutions. Notes one observer, 'the relatively comfortable state of Thai science may be rocked to its core in the not-too-distant future if some universities decide to take up a proposal now being considered and leave the secure confines of the civil service to become quasi-independent' (Fahn, 1991: F3). The proposal has divided the Thai scientific community into several issue segments. One dimension of opinion believes that they can profit from market demand and the other believes that they cannot. In general, university personnel in the applied social and natural sciences, and engineering fields favour greater freedom for universities to offer competitive salaries because they are the ones in demand. Personnel in the basic social and natural sciences, and humanities are less optimistic about beneficial effects to universities from exiting the civil service. Employment security is another area of concern. Even though salaries are not high, positions are secure and promotion is almost automatic. However, some see employment security as an important cause of the lack of competitiveness of Thai science. A 'publish or perish' ethos is being advocated to make it obligatory for university professors to maintain currency. In highly demanded technical fields, universities are seen to need to compete with the private sector and keep productive researchers on campus. Unless universities can maintain technical currency for teaching purposes, Thailand will have to send another generation of students abroad to fill the positions which will fall vacant when the present generation begins to retire at the end of the decade. A final area of concern involves the capability of the public university system to survive in a quasi-independent situation. Some consider that 'many universities would fail' but that the system as a whole would be improved (ibid.: F3).

Although several public universities have prepared plans for receiving greater administrative autonomy from the government, the overall framework of 'privatization' has not been clarified. In the background of the debate over the advantages and disadvantages of privatization of public universities in Thailand is a set of assumptions about how well each institution could increase its income from students and clients compared to competitors, the effects of this redistribution of income within the institution and the degree to which government assistance would cover other operations. However, as Thai universities jockey to position themselves in lucrative fields of human resource production, the research and technical service functions of higher education have moved into the background. The implications for graduate education and research need to be carefully considered. As one observer puts it,

> . . . the picture at the moment is not very encouraging. Faculty in key fields are being hired away by the private sector and to a lesser extent by new universities and new programs in these fields at existing universities. There is thus a real threat to the nation's ability to train the next

> generation of faculty and the highly skilled manpower increasingly needed in industry and in formal sector service firms (Myers, 1991: 12)

The new system will probably be more responsive to short-term social needs. After all, it took more than seven years for Thai universities to respond to the shortages in technical manpower observed in the mid-1980s (Sripaipan and Brimble, 1991). But there is the danger that 'privatization' is viewed as a panacea for all the problems of Thailand's economic and technological development. In particular, 'the case for S&T training programs which often require large expenditures on equipment and supplies may be difficult to raise under conditions of financial autonomy' (ibid.: 14). Furthermore, the greatest scope for increased income for universities lies in increases in tuition fees, raising issues of equitable access to higher education.

## Thai S&T Infrastructure and the Emergence of S&T Policy Organizations

Two key problems have emerged in the Thai innovation system in the past decade. One is the difficulty experienced by the educational system in delivering human resources with appropriate skills in a timely manner. Unfavourable quantitative and qualitative characteristics of the labour force are viewed as key constraints to science-based technological innovation in the private sector; there are 'critical S&T manpower shortages', especially at the university degree level. The 'supply of human resources . . . does not match demand in the labour market' and 'new projects . . . require a high level of scientific and technological competence' that many firms do not possess (NESDB, 1986: 155–56). A multi-objective strategy for the improvement of human capital is required, including the reinforcement of graduate teaching and research, and vocational training (Dahlman et al., 1990; Sripaipan and Brimble, 1992).

The second problem in the Thai innovation system is that although demand for technically qualified human resources is strong within the Thai industrial sector, demand for R&D and externally-procured technical services is weak. Thailand's national industrial structure is considered not to lend itself to private investments in R&D and, consequently, technological innovation. There are believed to be too many small, family-owned firms that cannot afford to invest in R&D, or there may be too many large foreign firms and joint ventures which rely on the R&D capability of the parent company. These particular patterns of entrepreneurship are said to discourage long-term investments in product innovations and improvements in the manufacturing or distribution process (see TDRI, 1994; Brimble and Sripaipan, 1994).

Studies usually propose various policy remedies to trigger a process of technological accumulation in Thailand so that the country can break out of its current technological trajectory and provoke 'changes in the Thai economic structure away from agriculture toward industry' (NESDB, 1986: 152–55). Two principal groups of constraints to technological development are identified. For many Thai S&T planners, the main policy problem is to raise private sector R&D expenditures (Kritayakirana and Srichandr, 1990). Overall, industry in Thailand does not invest in R&D. Only about 14 per cent of R&D expenditures was financed by productive enterprises in 1985 (Lall, 1990). A 1982 survey of Thai firms showed that research budgets represented a meagre 0.01 per cent of sales revenue (Yuthavong and Sutabutr, 1983), a figure that is well below private sector spending for technology development in Asian NICs. Firms judged to have some capacity for technological innovation had on the average fewer than two staff assigned to this work, most of whom did not possess any university level scientific or technical training. Although lacking significant research capacity themselves, the firms were not using the resources of universities and government scientific institutions; only 2 per cent of research expenditure was contracted out of these institutions or their staff.

The policy emphasis is therefore on identifying and removing disincentives to investments in R&D in a fast-growth, export-led economy in which most major production facilities are branch plants of foreign firms. Analysts believe that in this sort of economy, fast growth sharply reduces the need to raise production efficiency. High tariff protection has resulted in low domestic levels of competition and certain fiscal disincentives such as import taxes on capital equipment, income taxes on foreign consultants and absence of positive fiscal incentives such as tax credits for R&D are held responsible for hampering the deployment of R&D activities in the private sector (TDRI, 1990b). The system of financial incentives to stimulate industrial innovation, such as grants and R&D tax write-offs, needs strengthening as well (TDRI, 1990a and b, 1993).

Rapid growth of assembly operations for export of manufactured goods has led to a shortage of engineers and technical personnel which 'is posing the most serious bottleneck for the further industrial and economic development of Thailand' (TDRI, 1990b: 50). Some demand also appears to be developing for technical services and technology management skills. These trends will put pressure on Thai manufacturing firms to upgrade their technological capabilities.

The second group of constraints has to do with the inadequacies of the Thai S&T infrastructure (TDRI, 1993). One important shortcoming is the weak technical service sector to provide S&T consultancy, information, standards, calibration and testing, prototyping, etc. Few free-standing organizations exist to service sectoral technical problems. Existing S&T information centres 'cannot describe either the R&D conducted in this country, or the technical and consultancy resources which are available in universities' (TDRI, 1990b: 50; see also TDRI, 1989b).

These are the conclusions that Thai policy makers have arrived at after a decade of serious S&T policy efforts, including the development of S&T analysis skills in such institutions as TDRI. In the following sections we examine more closely the emergence of key Thai S&T policy strategies and institutions.

## S&T Strategies in the National Economic and Social Development Plans

Thailand's economy developed on the basis of extensive agriculture in response to its endowments of large areas of cultivable land and few densely populated areas. Rice and rubber exports provided linkages to the international economy. Minor manufacturing activity was controlled by foreigners. The 1932 military coup created a constitutional monarchy and also a nationalist policy of industrialization. The strategy adopted was based on import-substitution via state-owned enterprises in rice milling, sugar refining, smelting, cement and rubber products. After 1958, the policy changed to one of promotion of private investment through adequate regulations, and promotion of appropriate infrastructure and manpower. Investment promotion targeted the consumer goods industry, which was highly protected.[5]

Since 1961, the Thai government has issued seven national development plans. S&T is given only superficial treatment in the first four, and although the Fifth Plan (1982–1986) had a chapter on S&T, technological goals and strategies were not clear due to lack of information and experience (Dahlman et al., 1990: Annex 2). It is instructive to examine the ways in which preoccupations about industrial innovation have emerged.

The First Plan (1961–1966) reiterated the strategy of promoting private investment in industries using local raw materials or substituting for imports. The role of the state was to develop infrastructure in transportation, power and communications. Public research and technical assistance was promised in agriculture, mining and public health. The Second Plan (1967–1971) added to the private investment-promotion strategy an emphasis on employment generation through the support of cottage industries and joint ventures with foreign firms. The Plan included projects for research and technical support in standardization, agriculture, public health and agro-industry. The Second Plan maintained the orientation of the first, while also insisting on social development. The idea that human resources would be a determining factor in the successful application of the Plan was largely accepted, and consequently a national programme for the development of professional education was implemented.

By the time of the Third Plan (1972–1976), the difficulties of the import-substitution strategy had become apparent, and a strategy of export-promotion was adopted to correct balance of payment problems with duty exemptions, tax breaks and industrial estates. The Thailand Institute of Scientific and Technological Research (TISTR) was given the task of conducting research on materials and product development (MOSTE, 1988). The Third Plan emphasized the need to increase production while reducing the growing gap in social services between the metropolitan area and the regions. The Third Plan also emphasized the necessity of developing adequate supplies of scientific and technical personnel. A Technology and Environmental Planning Division was established in 1975 in the Office of the National Economic and Social Development Board (NESDB) in order to formulate a national S&T development plan and a national environmental plan as integral parts of the national development plan.

The Fourth Plan (1977–1981) strengthened the investment-promotion mechanisms deployed by the government (subsidies, tax breaks, guarantees, etc.), but continued to provide protection for import-substituting industries. In this Plan, the government acknowledged the significance of S&T, called on the increased use of S&T for industrial productivity and announced that national S&T organizations would be upgraded. It was during the Fourth Plan that MOSTE was established in 1979 with overall responsibility for planning, coordinating and promoting S&T within the government (UNESCO, 1985).

The Fifth Plan (1982–1986) recognized the costs incurred by encouraging highly protected import-substituting investments: too many inefficient, uncompetitive industries with weak backward linkages concentrated in the capital. The Plan emphasized industrial restructuring, regional development through small-scale industry, further export promotion, and increased efficiency, productivity and quality in existing industries. This Plan included an explicit S&T chapter which called for the upgrading of S&T institutions, extensive technology dissemination, more vigorous use of technology in firms and enhanced international cooperation (MOSTE, 1988).

Thailand's Sixth Plan (1987–1991) continued the emphasis on export promotion, productivity, efficiency and quality. It stressed the importance of investments in S&T: 'serious and continual development . . .coupled with good management and services are vital if Thailand is to increase her standing in the intensely competitive world markets which she faces today, and raise the standard of living of her people' (NESDB, 1986: 150). It identified a number of problems in the Thai S&T system, notably under-investment in S&T, excessive payments for foreign technology and weak production of human resources. Three factors causing these problems were identified:

> lack of a policy and master plan on science and technology, . . . lack of an effective central coordinating agency in science and technology,

> [and] lack of interest among private users of technology in the development of science and technology as a means of increasing production efficiency (ibid.: 157–58).

The Seventh Plan (1992–1997) identifies three successful outcomes of past S&T policy efforts. First, a policy environment has been created in which S&T is taken seriously. Second, dedicated S&T promotion organizations have been established in the public sector in three key areas: biotechnology, micro-electronics and materials, and a variety of instruments, mechanisms and inducements are in place to encourage R&D and innovation in the private sector. Third, initiatives to produce high level S&T manpower are showing results and extensive scholarship programmes for overseas study are in place. It identifies as key problems the limited application of technology to increase productivity, limited capacity to acquire and transfer technology, inadequacy of the quantity and quality of S&T manpower, and weaknesses in R&D facilities and support facilities. The Seventh Plan is novel in three respects. First, unlike previous plans, it proposes several quantitative targets for S&T development regarding manpower training and public investments (the GERD/GDP ratio is to rise to 0.75 per cent). Second, it begins to formulate a sectoral approach to technology development. Third, it expands the range of proposed innovation policy instruments and incentives compared to previous plans (NESDB, 1991).

## Thai S&T Policy Organizations and Delivery Mechanisms: From Research Coordination to Enterprise and Technology Development

Thailand's S&T policy establishment emerged in three waves. In the first, the foundations of a national research and technology support infrastructure were established. One institution—the National Research Council (NRC)—established in 1956, was given nominal responsibility for funding university research, coordinating the overall research programmes of public and private actors and advising the government on research priorities. In the second wave, beginning in the mid-1970s, dedicated S&T policy functions were developed within the government. An S&T policy ministry (MOSTE) was established in 1979, and the NRC and other scientific and technical institutions were placed under its auspices. Agencies responsible for economic planning (NESDB), investment (the Board of Investment), and industry policy and extension (the Ministry of Industry) came to address S&T policy issues, and S&T policy was integrated into the more general framework of government policy. Specialized programmes and institutions to promote key technologies were created. By the end of the 1980s, the country's S&T deficiencies were relatively well-known and in the course of the Sixth Plan experience had been gained in developing and applying a range of policy instruments to remedy them. In the third wave of S&T policy development beginning in 1991, a new S&T support organization—the National Science and Technology Development Agency (NSTDA)—was created with a combination of operational and policy responsibilities to act as a '"driving force" for rapid S&T development' (NSTDA, 1991: 10), and ways were sought to make the higher education sector more responsive to Thailand's human resource needs.

The major departments under MOSTE until 1991 were the Office for Science, Technology and Energy Policy and Planning (a central policy analysis shop), the Technology Transfer Centre (which is concerned with terms of acquisition of technology), the Department of Science Services (offers testing and information services to industry), NRC, TISTR (the largest public research agency in Thailand with responsibility for applied research and technology support), the Science and Technology Development Board (STDB), and three specialized research centres to promote R&D in key areas of technology (biotechnology, advanced materials, and electronics and computer technology).

The STDB was the primary vehicle through which Thailand financed strategic R&D in advanced technologies. It was established in 1985. In 1991 its primary strategic research functions were rolled into the new NSTDA. STDB was established to administer a USAID programme of support for S&T. It had four elements: enhance interaction between users and producers of scientific and technological knowledge; promote policy review and dialogue; promote research, development and engineering (RD&E) in biotechnology, materials science and electronics; and supply industrial development support in the form of standards testing and quality control, technical information, diagnostics and technology assessment (Dahlman et al., 1990: Annex 2).

STDB was intended to fund designated RD&E, competitive RD&E, company-directed RD&E and RD&E support activities such as scholarships in the three priority areas of technology mentioned earlier. STDB received US $49.4 million for the period 1985–1994. US $35.4 million was contributed by USAID, US $19.6 million was a soft loan and the remainder a grant. The Thai public and private sectors contributed US $14 million (USAID, 1992). STDB was intended to offer 'grants and low-interest loans to the private sector to prompt it to develop its RD&E capabilities and enable the private sector to apply the R&D of local institutions and organizations to commercial and industrial uses' (*Bangkok Post*, 1991: 18). However, of the approximately US $7 million it disbursed between 1986 and 1988, about 90 per cent was used to support research universities and public laboratories; only two company-directed projects were supported (Dahlman et al.,1990: Annex 5). Between 1987 and 1990, STDB supported forty-two projects in biotechnology at a cost of US $7.1 million (Davis et al., 1993a).

In the 1980s, Thailand was able to combine a number of other sources of funding to support research in strategic technologies. In biotechnology, for example, the National Centre for Genetic Engineering and Biotechnology (NCGEB), one of the specialized technology centres under MOSTE, funded eighty R&D projects in biotechnology worth about US $4.4 million. Three other important sources of biotechnology R&D support in Thailand were available in a bilateral assistance framework with the United States. The Agricultural Technology Transfer Programme (ATT), a USAID programme supporting R&D projects conducted by the Ministry of Agriculture and Cooperatives of Thailand, funded US $8 million of biotechnology research in Thailand between 1985 and 1990. The US–Israel Cooperative Development Research Programme (UICDR), a USAID funded programme supporting joint bilateral R&D projects between Israeli scientists and those from developing countries, spent US $1.5 million in Thailand between 1985 and 1990. The Programme in Science and Technology Cooperation (PSTC), another USAID programme that funds innovative research in developing countries on a competitive basis, supported US $6.5 million of biotechnology research in Thailand between 1983 and 1990 (Davis et al., 1993a). The number of Thais winning PSTC grants is impressive: by 1990, Thai scientists had won fifty-three grants, more than twice the total awarded to any other country (USAID, 1992). Thailand is also the leading developing country recipient of UICDR awards (USAID, personal communication).[6]

In sum, Thailand's policy and delivery system for supporting RD&E, training and technical services in advanced scientific technologies evolved in the 1980s to a certain degree, within the framework of bilateral cooperation with the United States.[7] This arrangement was characterized by sharply focused investments in strategic R&D, primarily in Thai universities.

The situation in the 1990s promises to be very different. In the first place, the implicit strategy of driving industrial innovation through investments in university-based strategic research has been only a qualified success. In the second place, Thailand's public RD&E system is being transformed through the changes in the university system (discussed earlier), and also through the new missions and functions that NSTDA is bringing to the system. In the third place, the roles of international collaborators are likely to be very different in the coming decade. To conclude this article, we briefly discuss each of these issues.

The effects and, especially, pay-offs of concentrating public S&T investments in strategic university-based research have been mixed.[8] On the positive side, research projects often produced prototypes or processes and permitted numerous laboratories to be equipped with up-to-date equipment. The research provided training for many Master's students. Researchers often presented papers in local conferences or, less frequently, published in international journals. They also often became deeply involved in extension work and in providing technical support to users. Those researchers fortunate enough to obtain grants rarely wasted the sources. A number of researchers gained industrial credibility and developed personal linkages with industrial users. The donor, the United States, received a number of tangible and intangible benefits (ISTI, 1989).

On the down side, successful commercialization of products or processes did not take place as extensively as anticipated. Few cases of spin-off firms were reported; in most cases of successful utilization, the technology was captured and assimilated as an incremental innovation by an already-existing firm.[9] Senior researchers became so involved in managing scale-up, plant propagation or demonstration efforts that they were unable to pursue scientific research. In some cases, universities were offering subsidized technical services that undercut private service providers. The shortage of post-doctoral researchers made it unlikely that frontier research could take place. Two other factors steered the effort towards selection of easily harvestable areas of applied science. One was the STDB selection committee's emphasis on projects appearing to offer relatively quick applicability. The other was the demographics of the Thai scientific community: few universities had hired younger scientists and competition for scarce research money favoured senior scientists. As a result, investments flowed more easily towards mature technologies like tissue culture than towards sciences upon which next-generation technologies might emerge, such as molecular biology. In other words, seven years of strategic research investments did not adequately prepare the Thai scientific community to work in emerging areas of generic scientific technology. These investments have yet to take place.

NSTDA's strategy and structure appear designed to overcome three problems. The first has to do with creating a critical mass in priority areas of S&T. NSTDA anticipates having over 300 scientists working in three national research centres in generic technology by 1996. The second problem is the lack of integration of innovation support instruments. NSTDA combines a number of instruments to permit a systematic approach to industrial innovation, particularly downstream from research. In addition to the three centres, NSTDA will manage a centre for technical information, a programme for RD&E support in the private sector, a science park, an investment fund for commercialization of S&T, a fund for supporting RD&E in public sector institutions, and a fellowship programme for overseas and domestic studies. NSTDA's objective is to develop technology-based businesses in Thailand. NSTDA anticipates a budget of 3.5 billion Baht (about US $140 million) for 1996. The third problem that NSTDA addresses is that of the rigidity and lack of incentives in the public sector. NSTDA has been created outside the civil service and the state enterprise sectors. It is free to set its own rules with respect to employment and remuneration; to obtain funds from any sources; to borrow, lend and invest; to recover costs and retain income; and to independently enter into agreements. In other words, NSTDA is an enterprise and technology development agency, a research funding agency and a dedicated research agency.

The concentration of these functions in one public agency did not reassure all observers. Those familiar with the record of intramural R&D in public laboratories such as TISTR were apprehensive that the three new centres might follow suit. While Thai proponents of NSTDA pointed to the successful use of institutions such as the Korean Institute for Science and Technology (KIST) to incubate capacity in advanced technologies, representatives of American donors were reluctant to invest in the development of public sector intramural R&D capability in Thailand.

## Conclusions

Rapid economic growth is placing severe strains on Thailand's S&T infrastructure, which is mainly in the public sector. Thai universities and research institutes were widely viewed in the past decade as public goods, from which benefits could be taken but which required little cultivation. The private sector is far more attractive than the public sector to those with scientific or technical skills in demand—mainly applied sciences, engineering, informatics and business disciplines. Basic sciences are languishing and university research careers for young scientists are not secure. Furthermore, no one is looking after next-generation technologies except a handful of visionaries in the Thai S&T policy establishment.

The Thai scientific community is a necessary but not sufficient element in the process of industrial development. Its role is likely to become increasingly diversified in coming years, as it is called upon to provide training, policy guidance, service to a variety of constituencies and evidence of excellence in the production of science.

Thailand's strategy of creating a strong core of public technology institutions while inducing the university system to respond forcefully to market demands for human resources bears some resemblance to Korea's. Two key differences are worth pointing out, however. In the first place, Thailand does not enjoy the consistently high-quality international networks among scientists and engineers that Korea enjoys. There are few Thai expatriate scientists to bring home and Thailand's scientific community is not highly internationalized. In the second place, Thailand's industrial structure is much less integrated than Korea's. The limits to technology spillovers from foreign direct investment are becoming visible, and mounting a very vigorous technological modernization effort does not appear to be one of the principal objectives of Thai S&T policy in the immediate future. As intra-Asian trade and Japanese investment increase, Thailand's technology strategy will have to come to grips with the threats and opportunities of being a late industrializer in an already large 'flock of flying geese'.[10]

## Notes

Acknowledgement: Part of the research presented here was supported while Charles Davis was with the Science Council of Canada by a grant from the International Development Research Centre (IDRC) to a team from McGill University and Mahidol University to examine communication of biotechnology research results. Another part of the research presented here was also supported while Jacques Gaillard was with the International Foundation for Science (IFS) by a grant from the Salén Foundation. These supports are gratefully acknowledged. Views expressed here should not be attributed to IDRC, the Salén Foundation or to any other institution.

1. In comparison, Singapore increased its Gross Expenditures on R&D/Gross National Product ratio (GERD/GNP ratio) from about 0.2 per cent in the late 1970s to about 1 per cent a decade later. Taiwan and South Korea increased their R&D spending from a level similar to that of Thailand's to about 2 per cent in the late 1980s.
2. This section draws on Gaillard (1990).
3. On the proliferation of engineering degree programmes in Thai universities, and the problems in funding and staffing them see Meyers (1991: 9–10).
4. Mathematics and computer science, medical and health sciences, engineering, agriculture, forestry, fisheries or basic science.
5. This section and the next draw on Dahlman et al. (1990: Annex 1).
6. Thai scientists have also been remarkably successful at winning awards from other international sources of competitive research funding. Between 1974 and 1991, about eighty Thai scientists received research grants from the International Foundation for Science (IFS), placing Thailand in the top four recipient developing countries in the IFS programme. It is also the leading Asian recipient of funds from the European Community's Science and Technology for Development (STD) Programme.
7. Thai scientists have been largely trained in the United States, but also in Japan and in a number of European countries, especially France, Germany and the United Kingdom. This diversified training strategy has no doubt facilitated the ability of Thai scientists to maintain a range of international contacts and collaborative relationships, even though the United States is the main donor. The success of Thai scientists in the European STD Programme is quite revealing of their capacity to develop collaborative linkages with European scientific institutions. For a thorough discussion of Thailand–US bilateral cooperation, see Muscat, 1990.
8. The following is based on Davis et al., 1993a, 1993b; TDRI, 1992.
9. In other words, investment in strategic research in Thai universities did not produce a swarm of new technology-based firms.
10. On the 'flock of flying geese' model of Asian regional industrialization see Ozawa (1991).

## References

*Bangkok Post* (1990). 'Bangkok Post Economic Review: Year-end 1990'. Bangkok: *Bangkok Post*.

——— (1991). 'Thailand Steps up Biotechnology Push'. 11 January, p. 18.

**Brimble, P.** and **Sripaipan. C.** (1994). 'Science and Technology Issues in Thailand's Industrial Sector: The Key to the Future'. Report prepared for Asian Development Bank, Bangkok, June.

**Clark, N.** (1987). 'Similarities and Differences Between Scientific and Technological Paradigms'. *Futures*, February, 16–42.

**Davis, Charles H., Thomas O. Eisemon, Yongyuth Yuthavong, Kitiya Phornsadja** and **Anadi Chungcharoen** (1993a). *Scientific Capacity and Technological Change: Universities, Industry, and Communication Strategies in Plant Biotechnology in Thailand.* Biotechnology International No. 10. Nairobi: African Centre for Technology Studies.

——— (1993b). 'Sociological Features of Strategic Funding of Scientific Technologies in Universities in Developing Countries: The Case of Biotechnology in Thailand'. Unpublished manuscript.

**Dahlman, Carl J., Peter Brimble, Rafael Herz** and **Atchaka Sibrunruang** (1990). *Thailand: Technology Strategy and Policy for Sustained Industrialization.* Washington, DC: The World Bank, Industry Development Division.

**Fahn, James** (1991). 'Publish or Perish? Some Scientists Urge Universities to Undergo Change, Leave Civil Service'. *The Nation* (Bangkok), 5 November, p. F3.

**Gaillard, Jacques** (1990). 'La communauté scientifique Thaïlandaise: un développement rapide mais une reproduction difficile'. *Inter-Mondes*, 1, 43–57.

**Ichikawa, Nobuko, Michael A. Cusumano** and **Karen R. Polenske** (1991). 'Japanese Investment and Influence in Thai Development'. *Technology in Society*, 13(4), 447–69.

**ISTI** (1989). *Thailand: Evaluation of USAID's Centrally-Funded Science and Technology Grants Program.* Washington, DC: International Science and Technology Institute, Inc.

**Komin, Suntaree** (1989). 'Social Dimensions of Industrialization in Thailand'. Monograph. Bangkok: National Institute of Development Administration.

**Kritayakirana, K.** and **P. Srichandr** (1990). 'Technological Capability of the Thai Industry: Status, Key Issues and Recommendations'. *ASEAN Journal of Science and Technology*, 7, 15–41.

**Lall, Sanjaya** (1990). 'Building Industrial Competitiveness in Developing Countries'. Monograph. Paris: Development Centre of the Organisation for Economic Cooperation and Development.

**Manunapichu, K.** (1981). 'Professions in Pure Science are Losing Popularity'. *Journal of the Scientific Society of Thailand*, 7, 37–40.

**MOSTE** (1987a). *The White Book on Science and Technology in Thailand* (in Thai). Bangkok: Ministry of Science, Technology and Energy.

——— (1987b). *Thailand Science and Technology Indicators.* Bangkok: Committee on Science and Technology Indicators, Ministry of Science, Technology and Energy.

——— (1988). *Science and Technology Policy: Development and Management.* Bangkok: Subcommittee on Science and Technology Policy, Ministry of Science, Technology and Energy.

**MUA** (1988). *General Information.* Bangkok: Ministry of University Affairs.

**Muscat, Robert J.** (1966). *Development Strategy in Thailand.* New York: Praeger Publishers.

———. (1990). *Thailand and the United States: Development, Security, and Foreign Aid.* New York: Columbia University Press.

**Myers, Charles** (1991). 'The Context of Higher Education Development in Thailand', in C. Nelson, N. Bhamarapravati, P. Koomsup and C. Meyers. *Thailand: A Case Study.* Conference report prepared for the Overseas Education for Development Conference, May.

**Nelson, Courtney** (1991). 'Research Capacity Building in Thailand', in C. Nelson, N. Bhamarapravati, P. Koomsup and C. Meyers. *Thailand: A Case Study.* Conference report prepared for the Overseas Education for Development Conference, May.

**NESDB** (1986). *Sixth National Economic and Social Development Plan (1987–1991).* Bangkok: National Economic and Social Development Board.

——— (1991). *Seventh National Economic and Social Development Plan (1992–1997).* Bangkok: National Economic and Social Development Board.

**OPM** (1984). *Thailand in the 1980s*. Bangkok: National Identity Office, Office of the Prime Minister.

**Ozawa, Terutomo** (1991). 'The Dynamics of Pacific Rim Industrialization: How Mexico Can Join the Asian Flock of Flying Geese', in R. Roett (ed.). *Mexico's External Relations in the 1990's*. Boulder: Lynne Riemer Publishers.

**Sripaipan, Chatri** and **Peter Brimble** (1991). 'Science and Technology Manpower in Thailand: Towards a Long Term Solution'. Paper prepared for the NESDB/UNDP project on Manpower Planning for the Development of Industrial and Service Sectors.

**TDRI** (1989a). *The Baseline Data Project: S&T Infrastructure and Development in Thailand*. Bangkok: Thailand Development Research Institute.

——— (1989b). *Final Report: The Development of Thailand's Technological Capability in Industry, Overview and Recommendations*. Bangkok: Thailand Development Research Institute.

——— (1989c). 'The Baseline Data Project: S&T Infrastructure and Development in Thailand'. Bangkok: Thailand Development Research Institute.

——— (1990a). *Thailand Economic Information Kit*. Bangkok: Thailand Development Research Institute.

——— (1990b). *Enhancing Thai Private Sector Capacity for Research: Development and Engineering—Final Report*. Bangkok: Thailand Development Research Institute.

——— (1992). *Case Studies of RD&E Performance in Biotechnology*. Bangkok: Thailand Development Research Institute Foundation.

——— (1993). *Private-Sector R&D: Lessons from the Success*. Bangkok: Thailand Development Research Institute.

——— (1994). *Endogenous Capacity Building in Science and Technology for Development*. Bangkok: Thailand Development Research Institute.

*Thai Life* (1985). 'King Mongkut, the Father of Thai Science'. *Science and Technology in Transition*, 3(2), 7–10.

**UNESCO** (1985). *Science and Technology in Countries of Asia and the Pacific*. Paris: UNESCO.

**USAID** (1988). 'Kasetsart University in Thailand: An Analysis of Institutional Evolution and Development Impact', in *A.I.D. Project Impact Evaluation Report*. Washington, DC: USAID.

——— (1992). *Cutting-Edge Research for Development: The A.I.D. Program in Science and Technology Cooperation*. Washington, DC: Office of Research, USAID.

**Watson, Keith** (1989). 'Looking West and Looking East: Thailand's Academic Development', in P.G. Altbach and V. Selvaratnam (eds.). *From Dependence to Autonomy*. Dodrecht: Kluwer Academic Publishers.

——— (1991). 'Thailand', in *International Encyclopedia of Higher Education*. New York: Garland.

**Wyatt, David K.** (1984). *Thailand: A Short History*. New Haven: Yale University Press.

**Yuthavong, Yongyuth** (1986). 'Bibliometric Indicators of Scientific Activity in Thailand'. *Scientometrics*, 9, 139–43.

**Yuthavong, Yongyuth** and **H. Sutabutr** (1983). 'Scientific and Technical Manpower and Research and Development in the Private Sector in Thailand'. *Journal of the Science Society of Thailand*, 9.

# Part 3

# Scientific Communities in Latin America

# 11 Bitter Harvest: The Growth of a Scientific Community in Argentina

**Hebe Vessuri**

Together with Canada, Australia and New Zealand, Argentina may also be classified in that small category of countries known as 'regions of recent settlement'. By the end of the nineteenth century, all these countries were characterized by an abundance of land relative to labour and capital. During the twentieth century, most of them became modern industrial societies. Argentina, however, since the 1920s has been unable to build the society that most Argentines envisioned, nor has its economic growth matched that attained by countries of comparable standing at the beginning of the twentieth century. Uneven and ultimately failed development became a problem in Argentina ever since the early decades of this century. Although it possessed some requisites for becoming a modern country—not the least being its high rate of economic growth between 1880 and 1930—those conditions did not suffice. In retrospect, government policies during the 1940s appear to have been short-sighted and political instability set in (Korol, 1991). Past economic growth helped raise expectations that could not be met. As a result, mythical views of the past tended to prevail. A better understanding of the Argentine past requires more complete knowledge of Argentine economic and social history. A number of issues remain obscure. This paper contributes to the understanding of the difficult consolidation of a scientific community in the course of the last hundred years. As in other peripheral contexts, the history of Argentine science is littered with examples of valuable endeavour followed by collapse, unbounded optimism followed by pessimistic indifference, and a lack of public trust in long-term intellectual endeavour.

## The Elements of 'The Promise'

The Argentine 'promise' consisted of the combination of European immigration, universal education, European capital and natural wealth. This is supposed to lie at the bottom of the 'miracle' of the 1880–1930 period.

With regard to the first aspect of immigration, Argentina is second among the nations that received the largest contingent of European immigration in the century extending from approximately the middle of the nineteenth century to the 1950s. If we take into account the immigration volume in relation to the total size of the receiving population, the Argentine case is even more outstanding, for it was the country that had the largest European immigratory impact during that period. On the other hand, Argentina is today one of the most urbanized countries in the world, with approximately 80 per cent of its population residing in urban conglomerates; international migrations in the first place and domestic migrations later were the main demographic factors that determined such urbanization (Lattes and Sautu, 1978). Already, by the turn of the century, Buenos Aires was a cosmopolitan city from the point of view of its population.[1]

The children of immigrants formed part of the broad contingent that benefited from the increase in the literacy rate and schooling, which leads us directly into the second aspect—education.[2] Around the 1880s, the structure of education at all levels suffered deep changes. Argentina, the same as Uruguay, Costa Rica and, to a lesser extent, Chile, accompanied its incorporation into the world market as an exporter of raw materials and an importer of manufactured goods, with a social and legal organization that involved the inclusion of all the population in the basic circuits of cultural diffusion. The global mass of population had access to a minimum of basic schooling aimed at guaranteeing cultural homogeneity (Tedesco, 1985). The progressive Argentine democratic free public school was aimed at spreading secular values, republican principles and a certain scientistic outlook which reflected the cultural order of the most dynamic sectors of society. The elite had access to more elaborate intellectual manifestations in the universities.

These educational changes had a deep and long-lasting impact on society. By the 1920s, the growth of secondary schooling was massive. Many young people got started on the road to upward social mobility through education. They entered the university or began to dispute places in the cultural domain and the liberal professions. Argentina was the Latin American country that achieved the earliest institutionalization of science. Indeed, with 27.8 per cent of qualified human resources in the economically active population (EAP) in 1950, the availability of highly qualified staff was not a problem for scientific and technological national development, except for individual specialities. More problematic, however, has been the country's inability to retain its scientists.[3] As to the third aspect, that is capital, around 1918 Buenos Aires, the door to the 'world's granary', was the second Atlantic city after New York. Except for commercial centres of import and distribution such as in Holland and Belgium, no other country in the world imported as many goods per capita as Argentina. In 1911, its foreign trade was larger than Canada's and one-fourth that of the United

States. In 1914, the per capita income of Argentina equalled that of Germany and the Low Countries and was higher than that of Italy, Spain, Switzerland and Sweden, having grown at an annual rate of 6.5 per cent since 1869.[4]

Nevertheless, in contrast to an older image, recent literature gives a more nuanced image of Argentina's fantastic natural endowment. It was never as rich a country as Australia, although its rate of growth was remarkably high. It has been argued that the most important differences between these two countries are in their immigration policies which affected their GDPs.[5] Also, in contrast to a diversified Canadian dominant class, where mercantile, financial, and eventually industrial interests had to compromise with agrarian groups, the large pampas landowners (the famous beef producers) were the exclusive dominant class in Argentina, being only concerned with cattle raising (Solberg, 1987). This class helped consolidate a pattern of land tenure that made medium and small owner–farmers more the exception than the rule on the Argentine pampas. Rather, a system of itinerant tenant farmers made possible the rise of grain cultivation in Argentina. This system, however, was undermined by government policies that made it almost impossible for farmers to buy land and did nothing to lower railway rates or to improve agricultural research, technology and market systems.[6] Another difference seems to lie in the import-substitution programme that, particularly since the 1960s, became the core of capital accumulation and reproduction. Industrial production was directed towards the internal market, and this strategy proved to be an obstacle to further growth due to market limits. Problems inherent in industrial expansion did not assure a process of long-term, self-sustained growth. Alternative policies could have been developed, but it is far less obvious whether a social base existed to support them or that they would have been viable in the international context of the times.

## The Stage of Scientific Institutionalization

### Formative Period: 1880–1915

Towards the end of the nineteenth century, the country started a process of economic and political reconstruction marked by an expansion of the export economy and a consolidation of the civilian oligarchy. European positivism was received favourably, for reasons partly political, for it offered intellectuals and politicians a conceptual scheme to situate history and society within a framework of progress, reinforcing a sort of 'official ideology' of the civilian elite. It was basically an adherence to a certain moment of European culture, mostly as participation in the reservoir of ideas, notions and attitudes that constituted the nineteenth century's legacy, as it was perceived at the closure of such a rich era.[7]

The achievement of an appropriate institutional context wherefrom men and their theories could become stronger was strenuously won, and the source of legitimation was almost inevitably linked to the representatives of the scientific centres in the metropolitan countries. Such was the case of the American astronomer Benjamin A. Gould, who was in-charge of the Observatory at Córdoba for fifteen years from 1870 to 1885, making it the leading scientific institute in the country, and who produced a magnificent work about the southern skies.[8] But given the fact that a large proportion of the few resident scientists were expatriate Europeans and that there was no local scientific tradition, and due to the sheer discrimination of locals by arrogant and rigid European teachers or researchers, it was not rare for conflicts to arise for authority and legitimacy. It was not always easy for a native scientist to prove his worth in a particular field. The struggle for recognition and power of palaeontologist Florentino Ameghino, a self-taught disciple of Herbert Spencer, in his confrontation with German zoologist Karl Burmeister is a case in point.

For a long time Burmeister was in a powerful position as director of the Buenos Aires Natural History Museum and prevented Ameghino from developing his scientific career locally until long after Ameghino became recognized in European circles. Argentine palaeontology had reached a critical mass, contributing an original approach to evolutionary studies. Among the signals of maturity were the presence of an interconnected disciplinary group, the control by this group of one of the two first-rate museums in Argentina (the one at La Plata), the support of the Ministry of Education and extended contacts with the European research front (Ameghino's early works were published in France and the United States and he kept intense contact, even an active collaboration with Henri Gervais, one of the great figures of French transformism).[9] Ameghino rallied to his cause nationalist forces that gave him support (Glick, 1982). However, Burmeister's resistance to the Argentine researcher was such that even at the point of death he appointed someone else as his successor to direct the Museum, although Ameghino was considered by the Argentine government to be the most adequate candidate.

The key institutions of the new 'positive science' were the observatory, the natural science museum and the university, typically structured as almost independent 'faculties' in the French sense, to which the other two kinds of institutions became linked. The three universities in this period were the ancient National University of Córdoba (UNC), that of Buenos Aires (UBA), and the newly created National University of La Plata (UNLP). In the UNC (founded in 1613), in the heart of the country, the weight of the traditional oligarchy and of the clergy was stronger than in

Buenos Aires. Science in Córdoba, as in most other Latin American universities, was subordinated to liberal education. Scientific topics were taught because they were assumed to discipline the mind, but most science teaching did not go beyond elementary notions. Students had to learn physics and mathematics not to become scientists or engineers, but to improve their education. With few exceptions, science was taught by the methods of reading and recitation. Students rarely entered a laboratory to question nature, but learned in one or more text-books what nature ought to say. Not infrequently, teachers were priests who responded to the Church hierarchy. But the University was ripe to produce its own transformation. A growing feeling of frustration within the academic profession and among students exploded soon after the first Unión Cíivica Radical Party got into office in 1916, which I take as the beginning of the second stage. It was at UNC that the University Reform Movement of 1918 exploded, to which most of the university community adhered, both in Argentina and in the rest of Latin America,[10] and which gave origin to the 'peculiar Argentine system' of university co-government by teachers, students and graduates.

Since the last decades of the nineteenth century, there had been growing contact between the University of Buenos Aires and *porteño* society. By the centenary celebration of independence in 1910, the university already had 4,000 students who had begun to organize themselves in the Student Centres of Medicine (1900), Engineering (1903) and Law (1905), and continued to grow incessantly in the following half century. The renewal task, delayed since the mid-nineteenth century, was urgent: positivism had meant the first effort in the country to give professional dignity to activities linked to science and culture. That effort, however, was undermined by the insufficiencies and dilettantism of many of its protagonists. The predominantly professional orientation of the University had not disappeared and (except in part in the case of the Faculty of Exact Sciences)[11] an authentic and deep scientific–cultural concern was absent (Halperín Donghi, 1962). A radical change of work style in the scientific and cultural domains was demanded and a tradition of research got established in several research institutes, from those of Ethnography and Historical Investigations, created in 1905, to the Institute of Physiology (1919), where Bernardo A. Houssay would begin to contribute to international science.

The University of La Plata was the embodiment of a project for the institutional development of the natural, physical and exact sciences started in 1905 on the basis of pre-existing non-university institutes. Its promoter, Joaquiín V. González, wanted to establish a modern university with strong emphasis on research, following the museum—institute—faculty model, better adapted to the 'taxonomic' natural sciences. Germany had a decisive role in the profile and level of science at La Plata (Pyenson, 1984). From the beginning of the century, this country wanted to gain influence in Latin

America and, acknowledging Argentina's leading role in the region, tried to get advantage from it. With the support of the Imperial Department of Foreign Relations, German science became implanted in La Plata in open competition with North American interests in the local context. The development of physics was entrusted to Emil Bose, one of the first students of Walther Nernst's physical–chemistry institute in Götingen.[12] In La Plata, Bose got the services of Johann Laub, who in turn was Einstein's first scientific collaborator, and of Konrad Simons, a pupil of Emil Warburg, for teaching electrical engineering. It has been argued that in 1913, La Plata was the major centre for theoretical physics outside Western Europe and maybe even outside German-speaking lands (Pyenson, 1984). German tradition in the basic sciences dominated Argentine scientific research until 1950.[13]

Around these three institutional centres grew the core of Argentine science during this stage, very strongly concentrated in the Buenos Aires–La Plata axis and the Mediterranean traditional cultured centre of Córdoba. Many a professor taught both at La Plata and Buenos Aires. The international trend of development of scientific laboratories received government support, with special concern for public health and agricultural production.[14] The state laboratories and research centres for a while became a model in their kind.[15] The new intellectual climate also led to innovations in secondary education. The National Institute of Secondary School Teachers was founded in 1904 in Buenos Aires following Prussian educational models. Between 1904 and 1913, some twenty foreign teachers were hired for this school, almost all of them German (Babini, 1954). Vocational training was provided by some technical institutions. The earliest industrial studies began in 1898 when an industrial department directed by engineer Otto Krause was added to the Secondary School of Commerce in Buenos Aires. The department later became the National Industrial School, known by the name of its first director and crucial in the development of technical education.

In the early decades of the twentieth century, there was a new social demand for technical rigour and its corresponding specialization. Already dozens of graduates in medicine, law and engineering occupied positions in a society that was becoming more complex. Individuals with scientific education were rapidly assimilated into the state bureaucracy. An incipient scientific market had emerged. Agricultural experimental stations, the modernization of cities and ports, etc., were clear manifestations of progress and industrialization. The entrance of science into the public arena at this early stage of institutionalization meant its increasing dependence upon public administration. The state was the main patron of research and educational programmes in the universities and remaining knowledge institutions.

Since the turn of the century, the governments of most countries in Western Europe and the United States competed in the field of scientific relations as they did in many other more mundane fronts. All created similar agencies and all chose Buenos Aires as their main point of entry into Latin America. France founded the Alliance Francaise for cultural diffusion and the Instituto Francés de Buenos Aires (1921) (later known as the Institut de l'Université de Paris à Buenos Aires), although the political interest of French authorities did not satisfy the expectations of Argentine demands and the financial means of the institute were always meagre (Petitjean, 1989, 1992).

In the scientific and cultural fronts, the United States began to participate actively in Latin America since the First Pan-American Scientific Congress which took place in Santiago de Chile as part of a broader strategy to consolidate its dominant position in all the domains of inter-American relations in the early century (Sagasti and Pavez, 1988). Let it be known that in Buenos Aires, one year later, on the occasion of the Fourth International Conference of American States, it would manage to have it reorganized as a Pan-American Union with functions of a commercial bureau in Washington.[16] In connection with science in Argentina, the United States would become more active in the following stage, largely through individual universities and private foundations, among which were the Rockefeller Foundation that supported medical education and the physiological research led by Bernardo Houssay (Cueto, 1991, 1994), and the Guggenheim Foundation that gave fellowships to scholars like Salomón Horowitz, who was crucial in the development of vegetal genetics in Argentina and Venezuela (Vessuri, 1992).

Bose's premature death in 1911 did not end German influence in the La Plata project. Between 1913 and 1926, Richard Gans, who before going to America had been assistant to Nobel Prize winner Ferdinand Braun and had made a brilliant career in Tübingen and Strasbourg, supervised the first six theses in physics defended in an Argentine university, and he persuaded students to publish in German journals. Gans' most distinguished Argentine pupil, Enrique Gaviola, received a doctoral degree from Berlin in 1926. Gaviola also studied in Göttingen, Johns Hopkins, Carnegie Institution and Caltech. In those places he worked with von Laue, Planck, Meitner, Einstein, Hilbert, Courant, Born, Franck and other giants of modern physics (Bernaola and Grünfeld, 1989).

Spain too in this stage reinforced its links with Argentina. The Institución Cultural Española, created in 1914, was the result of an initiative of the Spanish colony in Argentina in 1912 to honour the memory of the Spanish scholar Marcelino Menéndez y Pelayo. The aims of the association were to make known and to diffuse in Argentina the scientific and literary work produced in Spain, through a chair that would be occupied by Spanish intellectuals in the Universidad de Buenos Aires, and the development of other activities directly related to the intellectual exchange between Spain and Argentina (Roca and Sanchez, 1990). Among the occupants of the chair were Ramón Menéndez Pidal (1914), José Ortega y Gasset (1916), Julio Rey Pastor (1917), Augusto Pi i Sunyer (1919) and Esteban Terradas (1927), who exerted great influence upon the local intellectual milieu. When the Civil War brought havoc in Spain, a considerable number of Spanish intellectuals fled to Argentina and other Latin American countries, making crucial contributions to the institutionalization of science and culture locally.[17] Italy contributed a significant number of teachers in the institutions of higher education and research laboratories. A distinguished one was mathematician Beppo Levi, a pupil of Tullio Levi-Civita, the creator of tensorial calculus, who settled down in Rosario (Babini, 1954). We still lack a global study of the Italian contribution to the formation of the Argentine scientific community.

## National Soul Searching: 1916–1945

The world of intellectuals and scientists changed rapidly in the inter-War period, stirred by renewed ideological currents resulting from the dominant spiritual uneasiness in Europe after the First World War and developments in some countries, above all Russia and Italy.[18] Workers strikes and student revolts constituted the backcloth of the deep transformation in Argentine society. There was the emergence of the communist and socialist parties. A revitalization of Catholic thought was also visible, specially in the apology of religious education. Confusion in a world undergoing great political and economic transformation and redefinition of the locus of knowledge and culture with regard to the state were matters of concern for the elite of writers, artists and scientists who wanted to elucidate national features.

The intellectual field not only became more autonomous and differentiated vis-à-vis other social domains, it added to its periphery individuals of immigratory origin from the outlying *barrios* and a culture in transition in comparison to the more homogeneous elite 'culture' that had characterized Argentina until the *novecientos*. Intellectual production grew significantly. The emergence of a middle class, concerned with national problems, created a whole new market for the Argentine author, stimulating the expansion of the publishing industry. The 'new' emerged as hegemonic value. The intellectual vanguard completed the 'modernist' movement of the first cultural nationalism of the 1880s, producing a 'peripheral modernity' (Sarlo, 1988).

An awareness of the remoteness of the Argentine periphery was densely and complexly assimilated. The universality postulated in, for example, Borges' *Historia universal de la infamia* was the one he cultivated all his life: by situating himself with cunning at the margins, in the foldings, in the dark zones of the central histories, this *rioplatense* sought what he believed was the only possible universality to which he could aspire. I cannot help comparing this with the attitude of Argentine Nobel Prize winner biochemist Luis Leloir, as recounted by Cereijido (1990). He thought it inconvenient to work on fashionable topics, for the number of publications involved was too high and, even though one might be willing, it would be impossible to read them all. In his opinion, one should choose forgotten topics, for 'any', if analyzed deeply and cleverly questioned, would become a little window into the unknown, and then it was up to one's ability to be able to make an important contribution.

The coming to power of the multi-class and multi-national Radical Civic Union Party in 1916 inaugurated a democratic experiment which, despite its limitations—particularly the inability to alter the socio-economic structure—allowed to a large extent the political democratization of the country (Rock, 1975). The 1930 revolution meant a return to power of the conservative forces and the re-establishment of a regime with a clear oligarchic profile. In general, the years until 1943, known as 'the infamous decade', were characterized by a combination of electoral fraud, open corruption and naked violence. Transformations in the university setting were seen as belonging to the democratic experiment and, therefore, the universities became one of the key arenas where political ideas were fought out. Since then, the public university and the scientific activity it lodged suffered the instability of political government interventions, dismissal of teachers, purges of students, censorships and the subordination to immediate practical ends of political domination or conservation of certain historical situations, in alternation with shorter periods of strenuous reconstructive attempts.

However, the history of science and of the university to which it was closely associated for a long time cannot be reduced to political history. The more visible universities continued to grow, with faster rhythm than until then. Most of the current faculty installations were built during the 1930s and 1940s to house students which already numbered tens of thousands. But less visible science was also making progress. Precisely in those conflicting years some of the research centres began to bear their most valuable fruits, while the coexistence of research and teaching in the university became more common.

In 1919, Houssay founded the Instituto de Fisiología at UBA's Faculty of Medicine, becoming its first director. The Institute imparted theoretical and practical teaching of physiology, biochemistry and biophysics for the Schools of Medicine, Dentistry and Pharmacy. Between 1919 and 1939, 216 authors published 1,037 works in Argentine and foreign journals, and other publications (Instituto de Fisiología, 1941). In the late 1930s, the Institute was in its apogee. Houssay had culminated his work on the hypophysis function; the hypertension group (Braun Menéndez, Fasciolo, Leloir, Muñoz and Taquini) competed vigorously—and successfully—with North American researchers for priority in the discovery of angiotensin;[19] Leloir and Muñoz isolated for the first time sub-cellular particles capable of realizing the oxidative phosphorylation; Foglia was making rapid progress in his work on rat diabetes; Cicardo made observations about nervous transmission, cronaxia, the influence of adrenal cortex and the biological function of the potassium ion; Orías was doing brilliant work on heart noises. Young people who would later make significant contributions to science, like G. Weber and A. Stoppani, were starting their careers as research assistants. A number of clinicians ascribed to the Institute also developed intensive research activity (Vessuri, 1991). The Institute was in fact a graduate school of physiology and biochemistry which has been unsurpassed in Latin America.

Also through Houssay's initiative the Sociedad Argentina de Biología was created in 1920s, with affiliates in Rosario and Córdoba cities, which published the *Revista de la Sociedad Argentina de Biología*. In 1934, the Sociedad Argentina para el Progreso de las Ciencias came into being, with funds to support research and to grant scholarships. Bernardo Houssay was its president until 1949. The Association published the journal *Ciencia e Investigación* and already in 1937 proposed the creation of a national council for scientific and technological research, that would come to fruition only twenty years later.

In the agricultural sciences, the teaching of genetics began in La Plata in 1915 with Miguel Fernández, who had got a doctoral degree in Germany. Also, since the beginning of the century, A. Birabén and A. Gallardo had been carrying out studies dealing with heredity and wheat improvement at the Agronomical and Veterinary Institute of Santa Catalina in Buenos Aires province, close to La Plata. Around 1930, the first immunological studies were produced under the direction of the German Wilhelm Rudorf. Among Fernández's pupils were Salomón Horowitz and Francisco Alberto Sáez. The three were responsible for the development of genetics until 1947, when they were forced to emigrate. Horowitz directed the first institute of genetics that functioned in Argentina since 1929, where a good portion of the best plant breeders of Argentina were trained, and since 1934 taught genetics at the Faculty of Exact and Natural Sciences. Among his contributions were those dealing with a constant wheat–rye hybrid, heredity to locust resistance in bitter corn, sugar increase in corn and the genetic determination of the sex of papaya (Mazoti and Hunziker, 1976). His Argentine story ended in 1947 when, being dean of the Agronomy Faculty at UBA, he was forced to emigrate to Venezuela where he created the Venezuelan school of vegetal genetics (Vessuri, 1992). In 1944, the Instituto de Fitotecnia was created in Castelar, depending on the Ministry of Agriculture. There, some researchers continued the Rudorf school: Vallega, Cenoz and Favret. When the National Institute of Agricultural Technology (INTA) was created in 1957, the Instituto de Fitotecnia became the Department of Genetics, and under the leadership of Favret produced important innovations in corn genetics (Bercovich and Katz, 1990).

The ups and downs of agricultural scientific research are reflected in the course of agricultural productivity in the country. If from the end of the nineteenth century to the beginning of the Second World War agricultural production in the pampas had an important growth, with features similar and productivity levels comparable to those in the large North American prairies, state 'deaccummulation' in the agricultural sector became particularly critical in the 1930s and 1940s. While the United States and Canada witnessed a second era of spectacular growth in production, thanks to the massive adoption of new technologies, in the Argentine pampas technical progress was paralyzed for lack of government and social interest, production stagnated and even receded for two decades until it resumed growth in the 1960s (Sábato, 1981; Brasky, 1988).

Since the late 1930s, another outstanding figure, Enrique Gaviola, back in the country after his successful years abroad, practically single-handedly tried to start the study of physics, astronomy, mathematics and chemistry in Argentina. He founded the Argentine Physical Society in 1942, abrogated for the creation of a National Research Council, tackled the problem of university education in Argentina and the absolute necessity of sending students abroad by the dozens. By 1945, just before the assumption of the new Perón government, a project of his was being discussed for the creation of a private university in which the best Argentine scientists would be involved. Disagreements in emphasis between Gaviola and Braun Menéndez led to a halt in the discussion (Mariscotti, 1985). When taking into account the relationships between government (that is, Perón) and local physics (that is, Richter and his fusion project),[20] the double tragedy of Gaviola and Argentina acquires a sadder tone. An exceptionally talented researcher, Gaviola's solitary labours found an unresponsive, short-sighted milieu, rocked by political strife and daily frustrations, which ignored his efforts and eroded his work. His seed met fallow ground (Bernaola and Grünfeld, 1989).

The well-known Argentine psychoanalytic movement had local roots, although its articulation with the International Psychoanalytic Association occurred after the Spanish psychoanalyst Angel Garma, who was trained at the psychoanalyst institute in Berlin, migrated to Argentina in 1938 fleeing from the Spanish Civil War. Garma and the Argentine Celes Cárcamo, who had travelled to Paris, joined a pre-existing local group led by Arnaldo Rascosky and Enrique Pichón Riviere (Balán, 1991). Some time later, Marie Langer, who had received psychoanalytic training in Vienna, joined them. Due to the bad international reputation of the country, based on the advancement of right-wing governments in the 1930s which hindered the reception of refugees, Argentina attracted only a minimal portion of the forced intellectual European exile before and during the Second World War. Different from many other professions, the psychoanalysts discovered soon that it was possible to prosper at the margins: nobody interfered with private work in the consulting office nor with the scientific endeavour of a civilian entity such as the Argentina Psychoanalytic Association (APA), which was careful of not calling public attention and not breaking the rules of the game established by the Peronista regime. Psychoanalysis has been the liberal profession par excellence.

## The Years of Developmentalism: 1945–1976[21]

The world economic collapse at the beginning of the 1930s forced Argentina to abandon its previous pattern of economic development based on the expansion of cereals and meat production and turn to import-substitution industrialization. Owing to strong state support, by 1946 there were approximately 85,000 industrial establishments with almost 900,000 workers. In 1958, industry represented approximately one-third of the GDP. By then the manufacturing industry became the main purchaser of technology. Easy manufacturing needs could be met by domestic technology, but most capital goods and core technologies had to be imported.

During the Peronista government, state emphasis centred on technological development. In 1945, the Technological Institute of the Department of Industry and Commerce was created; in 1951 the Argentine Antarctic Institute, followed by the Armed Forces Centre for Scientific and Technical Research (CITEFA) three years later. In the ensuing government, official attention was given to the development of the scientific domain, being influenced by juridical–institutional European models (particularly France) for the organization of the S&T sector. Thus, the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) was created to coordinate, orient and promote scientific and technological research, and to advise the national government on such matters. It fulfilled only the role of scientific promoter, mainly through the instauration of the Carrera del Investigador Científico (1960), which gave stability and continuity to the research endeavour, imposing norms of rigour and quality that were in general accepted by all succeeding administrations. Yet it failed as an advisory body because the government at the highest decision making level had not established objectives as to the role of S&T in social and economic enterprises. In the end, research policy was based on the needs and objectives of the scientists themselves, the interests of the armed forces in security-oriented research and goals of the Ministry of Education. Public S&T institutions were the outcome of personal initiative and they remained relatively autonomous, deciding on programmes and their implementation based on their own prerogatives.[22] The lack of coordination was almost complete.

Although there was a large increase in the number of researchers and university students throughout the decade, the developments of S&T (besides the Atomic Energy Authority—CNEA) reflected a clear lack of concern with domestic R&D. The share of R&D in the GDP fluctuated between 0.31 and 0.33 per cent. Only small fractions of public expenditures for R&D were devoted to the industrial sector, and these decreased with time. Even in the late 1950s, when the state sought to fuel the substitution process by actively promoting capital goods, domestic technology was not an issue. Industries in the dynamic consumer goods sectors, such as electrical machinery, automobiles and petrochemicals, grew much faster than the national technological capacity to supply industry's demands. The National Institute of Industrial Technology (INTI) was created in 1957 on the basis of a frustrated antecedent like the Technological Institute of the Ministry of Industry and Commerce established in 1945. Financed by a 0.25 per cent tax applicable to all bank credits to industry, its aim was to provide technological services to industry through a network of laboratories and research centres and promote and support the development of research in industry. INTI was also supposed to provide industry with financial aid, but it did not have enough financial capacity to operate with autonomy. It did not have any planning power for the industrial sector (Oszlak et al., 1982). In the 1960s, it grew and diversified excessively, becoming bureaucratized and inefficient (Valeiras, 1989).

These developments coincided with the internationalization of big American companies. Argentina called on the multinationals, and they responded—at least for some years. Technological laissez-faire was embraced by decision makers at high levels of government and industry. Yet, despite the fact that the industrialization pattern adopted did not foster dynamic R&D systems, notwithstanding the blows against higher education, the strength of the modernization ideal helped university and governmental research to acquire momentum in some areas, particularly since the late 1950s. In 1945, with the consolidation of the military regime after the 1943 coup d'état, the new government entered the university as a defeated plaza and treated it accordingly. Despite official rhetoric to the contrary, the problems of the university sector became aggravated: a poorly paid professorate, laboratories without equipments, deficient installations and libraries without resources had to look after the unrestricted entry of new students in conditions of open demagogy. Incapable of defining its own objectives in the university domain, Peronism, which had begun by looking at the university as a political problem, ended ten years later visualizing it in police terms. The sacrifice of the university was thus useless to its own executioners (Halperiín Donghi, 1962). Ironically, when Houssay received the Nobel Prize for physiology in 1947,[23] he was no longer on the staff of the institute he had founded twenty-eight years earlier. Separated from his post by the Peronista regime on a technicality, he and Braun Menéndez founded, thanks to local private patronage, the Instituto de Biología y Medicina Experimental in 1943 (Foglia, 1980).[24] In 1947, another private science institution, the Fundación Campomar, was founded for research on biochemistry by a brilliant group of young biochemists who were the second generation of the Houssay tradition.[25] In his diary, H.M. Miller, regional director of the Rockefeller Foundation Natural Science Programme, recorded that they had 'discovered, identified and determined the structure of two coenzymes, which no group of enzyme chemists in the US had done'.[26] It may be mentioned that some years later, in 1970, its founding director, Luis Leloir, received the Nobel Prize for chemistry for work in the field of carbohydrate metabolism.

After the fall of the Peronista regime in 1955, reconstruction of the scientific domain began.[27] The Faculty of Exact Sciences at UBA was probably the most dynamic scientific institution in the ensuing decade. Many of the most creative efforts in S&T in the last forty years have derived from one or another group incubated there in that short period which ended in the 'night of the long sticks' (*la noche de los bastones largos*), the intervention of the university and the physically brutal eviction of teachers and students of the science faculty (Vessuri, 1987; Varsavsky, 1969; Slemenson, 1970).

Around 1957, the science faculty, the home of a brilliant school of mathematics, considered the possibility of creating an institute of calculus to influence the development of applied mathematics using the resources of automatic electronic computing. The leader of this movement was Manuel Sadosky, who had done his doctoral thesis under Spanish mathematician Esteban Terradas during the latter's exile in Argentina being initiated by him into applied mathematics.[28] The work carried out by the Instituto de Cálculo (IC) in its brief existence reveals the possibilities that Argentina had to become a scientific–technological pole in Latin America in those years of nascent informatics. After the virtual disappearance of the Instituto with the military coup of 1966, Sadosky organized in Uruguay the first computing group at the Universidad de la República; and Julián Aráoz, once out of the IC, initiated the first *licenciatura* in computational sciences in Venezuela within the Department of Numerical Calculus of the Sciences Faculty at the Central University of Venezuela, directed at the time by another Argentine mathematician, Carlos Domingo, who had also participated in the Buenos Aires experience.

Among its offshoots was the aborted development of a domestic electronics project in the 1960s and 1970s. The research efforts on electronics components, digital automation and industrial electronics at the UBA's engineering faculty in the late 1950s and 1960s came to a halt with the military coup of 1966, when many scientists quit the universities (and the country), while others went to work for multinational corporations or domestic electronics companies. Oscar Varsavsky was given a free hand by the owner of FATE, SA,[29] a private company that had made a fortune manufacturing tyres, to recruit the best electronics scientists, create FATE Electrónica, and start producing electronic calculators and printed and integrated circuits.[30] Initial success was due mainly to policies based on assimilating technology, training technicians and engineers, providing space for university researchers and producing products based on intensive R&D. The company did not use foreign licences and trademarks. Instead, it searched aggressively for non-proprietary technological information and sent technicians to study abroad. By 1975, the firm had captured more than half of Argentina's calculator market, forcing Olivetti (FATE's major competitor) into a deep crisis. The next step was computers. By 1974, a computer prototype called Serie 1000 was almost ready, but the whole project was scrapped between the end of 1975 and the March 1976 military coup. The project's ideological premise was that self-reliant development was possible and that the company could benefit from it. But the project lacked the backing of state institutions and technocrats willing or able to play a supporting role. Furthermore, Argentina lacked a systematic S&T policy and governmental awareness of the strategic relevance of producing domestic computers.

The history of atomic energy in Argentina is closely linked to the history of the CNEA, and the importance that President Perón gave to it through his support of the research work carried out by Austrian physicist Ronald Richter and his collaborators (Sábato, 1973; Mariscotti, 1985). In 1949, Perón approved a research programme to produce energy through controlled nuclear fusion. In November 1952, the High Temperatures Pilot Plant in Bariloche was closed and Richter relieved of his duties. Founded in 1951, CNEA began operations in 1953 under a military officer who, to offset the Richter fiasco, included on the staff all the better-qualified scientists, irrespective of politics—even enemies of Perón. It was another remarkable organization that attracted many capable Argentine scientists by offering good salaries, equipment and supplies for research, library facilities and opportunities for a number of the staff to go abroad on fellowships or travel grants at a time of extreme political and economic turmoil when most other scientific and technological enterprises were being suffocated by negligence and inadequate action. In 1956, it had a staff of about 400: 200 professional graduates, including thesis students, and the same number of technicians and others, a library with some 500 journals and clean laboratories, in good order and full of activity.[31]

In addition to a favourable international and domestic environment, other factors contributed to Argentina coming close to achieving its goal of nuclear autonomy during this most turbulent period of national history. The stability of institutional leadership in the CNEA (which until the 1980s came from the Navy), and the strategic thinking of Jorge Sábato as head of the Department of Metallurgy of the CNEA since 1955, created the tradition that Argentine research reactors were to be built in Argentina. Process turned out to be more important than outcome, as CNEA scientists acquired invaluable skills and learned how to produce technology while building the reactor. Sensing that CNEA know-how would have to be applicable to domestic industry before the nuclear energy industry would have any chance of success, Sábato (with the help of an Argentine industrialist) convinced CNEA authorities to set up an institution for technology transfer, the Servicio de Asistencia Técnica para la Industria (SATI). Another critical choice was the decision to do the feasibility study on Atucha I in-house. Sábato said later: 'We did not even know what a feasibility study was, but there was the understanding that we should do it if the CNEA was to learn how to produce technology' (Sábato, 1973; Sábato et al., 1978; Adler, 1988). As expected, the study called for the active participation of domestic industry, correctly forecasting that this step would be the starting point for a nuclear energy industry. Work towards autonomy in nuclear technology continued, even when many scientists left the country during the troubled years of the second Peronist government (1973–1976) and during the dark years of the ensuing military regime.

This development was aided by the broad appeal enjoyed by nuclear energy in Argentina. The power elites (with few exceptions) viewed nuclear electricity as a boon to achieving major national goals. Turned into a 'national project' that would redeem Argentina's pride, the programme appealed to the nationalist right for strategic and prestige considerations as well as the nationalist left which applauded decreased dependency on capitalist countries. Broad consensus allowed the CNEA to insulate itself partially from intra-governmental rivalries, bureaucratic bargaining, and the political and ideological conflicts between right and left, Peronists and non-Peronists, and civilians and the military (Adler, 1987).

The INTA was created on the basis of two central ideas: to develop an institutional converter mechanism for the adaptation of internationally available technology as a means to increase production, and to rationalize the use of scarce technical and financial resources. Financed by a tax of 1.5 per cent on agricultural exports, it had the clear aim of refuelling the agricultural sector and redressing the effects of the 1940s' most severe crisis induced by a combination of international and domestic factors. It was organized on the basis of restructuring the services of agricultural and cattle research, and the extension and promotion work of the Ministry of Agriculture along with an extensive training programme for research and extension service staff which was developed since 1960.[32] In 1964, it opened local MSc graduate programmes within the framework of the Graduate Programme of the Inter-American Institute for Agricultural Sciences (IICA), and in 1967 the Graduate School in Agricultural Sciences (EPGCA) was established by agreement between UBA, the Universidad Nacional de La Plata (UNLP), INTA and IICA.[33] INTA was special in the Latin American context in the sense that it managed to provide a favourable environment for professional development in research activity. The high functional concentration of the institutional model and its stability in time are linked to this. It only started to lose technical staff in 1966 and suffered a crucial loss and destabilization as a consequence of the application of the law of *prescindibilidad* sanctioned by the military regime when it came to power that year. INTA began to work on the improvement of agricultural practices, developing a body of recommendations that were already diffused in the early 1960s. All along it did research on genetics, results of which would be seen years later. The ensuing agricultural expansion was based on five crops having high degrees of technological innovation: hybrids in corn, sorghum and sunflower, exotic germ-plasm in wheat and a complex technological package in soybean. For quite some time INTA was the only official agent involved in the production of hybrids, because there was no local private enterprise activity capable of carrying it through and also because the types of corn required by the local market and ecological conditions prevented direct imports of seeds and lines from the United States. Both these elements made necessary a heavy stage of adaptive research which, of course, was carried out by the state through INTA.

Traditionally there was mutual mistrust between intellectuals and civil society organized in political parties, and thus participation of the former in public life was not a frequent feature until recent times. Distance vis-à-vis civil society was traditionally reflected in marginalization from the state, which under-utilized the social sciences considerably. Economists achieved an earlier legitimation, particularly since the 1950s, but they were not immune from entanglement with politics. An epitome of this is the case of economist Raúl Prebisch, who through the CEPAL which he inspired had less influence in Argentina than in many other countries of Latin America, although his ideas were originally developed specifically in response to his observations of Argentina. Many of his ideas and recommendations as well as those of CEPAL did not differ substantially in economic content from those of the Peronist and Frondizi governments. Yet, the meaning that these ideas acquired within the Argentine political context differed considerably because the various groups in Argentina sharing pro-industrialization and developmentalist ideas were often bitter political opponents. The story of Prebisch's influence—or lack of influence—in Argentina reveals a good deal about the role that ideas and their holders can assume in a divided and conflict-ridden society (Sikkink, 1988).

Yet, the lapse between 1955 and 1966 was decisive for the establishment of modern professional social science in Argentina, in contrast with previous traditions, although it revealed its fragility with regard to the strength which those traditions would show in the long run. The institutional base for this renewal was the university, with the creation of the Instituto de Sociología under the direction of Gino Germani at UBA, and some time later a programme at the Catholic University and at the University of El Salvador. But the discipline did not have enough time to consolidate. The 1966 coup d' état led to the massive resignation of full-time teaching and research staff, many of whom left the country altogether. The social sciences ceased to be collective enterprises with several projects of disciplinary consolidation. For a while, the shortcomings of the university institutionalization were partly overcome by the hospitality and cooperation of official and private institutions linked to some of the social sciences, such as the Consejo Federal de Inversiones (CFI), Consejo Nacional de Desarrollo (CONADE), Instituto Di Tella (1958), and Instituto de Desarrollo Económico y Social (IDES) (1960). These and other centres created in the 1960s and 1970s and the Latin American Council for the Social Sciences (CLACSO) (1967) would help to keep alive the social sciences in a milieu that would turn openly hostile after the 1976 coup.[34]

## Totalitarian Authoritarianism as a National Re-founding Experiment (1976–1983) and the Fragile Rediscovery of Democracy (1984–1989)

In the early 1970s, the style of development adopted for the previous forty years showed evident signs of exhaustion, with a pronounced deceleration of industrial growth and the economy in general. It began to be questioned by different social groups. At the beginning of 1976, with the instauration through a coup of a new military regime, such questioning assumed a radical nature and, for the first time in more than forty years, the patterns of economic administration were drastically altered. Indeed, the country witnessed an attempt at re-founding Argentine society through radical changes in its economic structure, its social base of support and the country's role in the international division of labour (Azpiazu, 1989). It involved the reversal of policies that were basic to the previous developmentalist paradigm, such as the ripening and acquisition of comparative advantages, the selective incorporation of technical progress, the strengthening of local technological capacity and the support of the scientific–technological system. Without recognizing that the national crisis, despite having local factors, was also an international crisis, the new Argentine policy adopted as central elements the generalized market liberalization and economic aperture. This was in sharp contrast with the behaviour of the advanced industrial countries, in which, in response to the crisis of the mid-1970s, the regulatory role of the state was enhanced and reinforced.

The international re-integration of the Argentine economy envisaged by the military was to take place on the basis of advantages linked to primary production (basically the humid pampas) and to its first elaborate stages. Yet, these activities were affected by the marked exchange rate lag that turned unviable any competitive possibility (not only in the international market but also in the domestic one) of local production. The dismantling of R&D teams and of the staff of professionals of public agencies in the scientific–technological domains, the interruption of the industrial ripening processes, the abandonment of local technological efforts, and the involution in process, organization and method technologies were only some of the results that, because of their nature, projected themselves as serious conditionings for any future strategy trying to establish hierarchies for the sustained and equitable growth of the Argentine economy (Katz and Kosacoff, 1988). The re-institutionalization of the country, since the end of 1983, has had to face much more complex and heterogeneous structures and patterns of behaviour than those that had matured during the previous stage of substitution industrialization. Also, the weight of the financial valorization of capital with a clear speculative content and the implications of this for the productive sectors, particularly the industrial one, meant a qualitative change, difficult to revert, relative to the situation of the early 1970s (Azpiazu, 1989).

The difficulty of engaging in an aggressive technological transformation became particularly serious in view of the problem of external debt. As expressed by Ferrer (1987), since the 1950s until the mid-1970s, the economy had grown at a 4 per cent annual rate and domestic fixed investment represented about 22 per cent of the GDP. Although the country was far from achieving conditions of self-sustained growth and dynamic integration into the world system, it had considerable freedom to manoeuvre and to decide the orientation of its development and technological change. In the 1980s, on the contrary, while the GDP was at the same level as in the mid-1970s, the per capita product was 20 per cent lower and domestic fixed investments hardly represented 13 per cent of the GDP. At the same time, the country had lost its freedom to manoeuvre and decide the priorities of its development, and external creditors had acquired an unprecedented influence in resource allotments. From 1981 to 1986, Argentina paid US $30,000 million in profits and interests, of which creditors refinanced 10,000 million. The largest part, US $20,000 million was paid with internal resources, that is, with the superavit of the commercial balance and with reserves. Despite this extraordinary effort, the external debt increased by more than US $20,000 million between 1980 and 1986. This transfer of resources absorbed 40 per cent of the exports of the period.

When the military coup of 1976 completed the task of dismantling the universities that had started in the previous coup of 1966, exodus, death or '*prescindibilidad*' affected massive numbers of teachers and students. Illegality reached persons, researchers, theories, ideological orientations—indeed entire disciplines. This was perhaps the most severe blow in a series of authoritarian experiences, which left deeply distorted the public university institution. In the process, all areas of knowledge were affected.

The intervention in the universities meant, besides its devastating short-term effects of expulsion and marginalization of those scientists committed to modernization schemes, longer-term effects which would lead to new organizational forms of research. These were basically geared to removing research from the university domain and exercising a political- ideological control over these actvities, which was impossible to do in academic institutions. The power of CONICET grew together with a very substantial increase in its budget, which was intensively applied to the expansion and strengthening of what came to be called the 'system of institutes'; by 1983 there were 116 institutes depending on CONICET and seven regional centres aimed at scientific geographical decentralization. On the return of democracy, investigation of irregularities in the use of funds granted to the institutes and research programmes that proliferated in the 1976–1983 period resulted in a protracted legal cause and in the elaboration of a subsidies regime favouring transparency in its handling, both as regards officials and beneficiaries of the system (Valeiras, 1989). The traditional scientific promotion subsidy mechanism was perfected since 1984 by means of the creation of the Projects of Research and Development (PID), where proposals approved were to be subsidized for three years; a complementary system was implanted to support projects for one year—the Annual Research Projects (PIA). Both programmes were conceived as policy instruments aimed at directly supporting the researchers and reducing significantly the role of organizational superstructures.

During 1987, CONICET financed a total of 2,275 fellowships in the country and 130 fellowships abroad in addition to maintaining the members of the Researcher's Career Programme, which in 1988 included 2,212 members, and the Research Technician and Support Staff Career Programme, which had 2,667 persons. Yet, a survey carried out by CONICET in 1988 gave a total of 19,111 persons devoted to scientific and technological activities. The exact and natural sciences prevailed, with notable weight of the basic sciences. In terms of numbers, this disciplinary grouping grew by 76.4 per cent between 1969 and 1982, and again by 21 per cent until 1988, well above the average for both periods (52.8 and 4.4 per cent respectively). By 1988, there was a partial recovery of the universities, which came to have 56.7 per cent of the scientific–technical staff (Albornoz, 1989).

Perhaps the most novel aspect of the actions in the last few years was the addition of the technological linking promotion function to CONICET through the Office of Technology Transfer. One hundred and thirty-one technological linkage agreements were signed between 1984 and 1988, while another ninety-four were carried out by units depending on CONICET and other institutions, signed only by other institutions. These figures acquire more meaning if one takes into account the economic crisis and the relatively small amount of money invested by private firms, mostly small and medium sized; it was evident that a considerable number of risk activities emerged without practically any state incentive. CONICET, without investing any additional money, began to optimize the use of resources of the scientific system.

The social sciences, identified by the military regime in the 1976–1983 period with subversive ideological penetration of the university, suffered the most direct attacks. They survived, reduced to a minimal expression in terms of numbers of active practitioners in precarious independent (that is, private) research centres which, in order to survive, adopted a 'catacomb mentality', including a low profile, little diffusion of their work, very restricted research topics and complete dependence on foreign funds (Vessuri, 1990; Brunner and Barrios, 1987). Towards the end of this very dark period, the delegitimated and marginalized social sciences oriented themselves towards a democratic discourse, built from the position of the defeated. Democracy came to be seen more as a hope than as a problem. Instead of a future radical transformation of society, the aftermath of the authoritarian experience led to a defence of the democratic tradition. The new conceptual apparatus moved to problems of political development, governability, public choice, institutional reconstructive reform, critique of the state and other topics common in the research agenda of foreign funding agencies and in intellectual centres in the developed countries. In a society like the Argentinian one, deeply disturbed, whose political history is characterized by situations of catastrophic tie and reciprocal veto, the idea of pacts and strategies of bargaining and governability constitute important innovations. Of course, concern for the reconstruction of the social tissue responded to the legacy of devastating dictatorships, but it was also influenced by neo-liberal claims towards the dissolution of the state.[35]

With the reinstauration of democracy, official and para-official foundations grew significantly, serving as communication channels for new ideas, and foreign foundations as funding agents and co-sponsors of new ventures increased. By contrast to the proverbial historical conflicts of intellectuals, technicians, professionals and even certain groups of bureaucrats with political parties, in the 1980s intellectuals entered strongly, not only into government circles as advisers and speech-writers (the Esmeralda group, for instance) but also in executive functions. Two important ministries, economy and foreign relations, were commanded by social scientists coming from independent private research centres, and a considerable number operated in pockets of the political administration (Passalacqua, 1989). A certain trend became visible towards the transfer of party power to sources of authority not belonging to any party and above them, the substitution of party representatives by experts in political posts, justifying it in terms of the 'technical' nature of decisions.

In the years of the military 'process', the emigration of the scientific, technical and professional cadres was very significant, adding to the problems of repression and marginalization. The abrupt application of the new model of economic opening since 1976 resulted in the breaking up of the industrial and technological systems and the devastating interruption of the ripening process in sophisticated industries like electronics, leading, among other things, to the significant growth of unemployment specially in the best qualified and better paid jobs—scientists, technologists, professionals and qualified workers (Azpiazu et al., 1988). From being an immigration settler country, by 1984 Argentina had a total stock of expatriates numbering 547,000 individuals, a considerable figure if the average educational level of the stock is taken into account as well as the fact of the considerable proportion of professionals and technicians it involved (Lattes, 1986).

Inadequate funding of higher education has persisted for several decades. While between 1960 and 1990 the total student population grew at a 5.9 per cent annual rate, public funding diminished during the same period at a 1.5 per cent yearly rate. The combined result was a substantial and sustained reduction of the expenditure per student, which passed from an annual average of US $1,800 in 1963 to US $225 in 1989—an average annual rate of reduction of 7.5 per cent. Higher education expenditure also diminished relative to secondary education to the point that at present there is no difference between the two levels. This situation has inevitably had an effect on the quality of higher education and scientific endeavour as a whole, in view of the close interface between science and higher education.[36] A recent study has found that professional schools suffered the impact more in the form of government and funding strategies in national (public) universities—these schools have the lowest level of teaching staff in terms of the proportion of full-time teachers. Instead, in the 'academic' schools, such as the science faculties, the teaching staff remains above the norm, although they are under-utilized as seen by the low levels of supplementary expenditure to that of staff (Gertel, 1991).

Since the 1970s, INTA's role diminished gradually as dynamic private firms began to competitively provide the market with corn seed. Also, the appearance of hybrid sorghums ten years after the corn hybrids, which involved an easy ecological adaptation of North American varieties, as well as of sunflower allowed the direct importation of foreign public technologies without the local public sector having to do any major adaptation work. This task was already carried out by private firms, be it subsidiaries of multinational companies or national enterprises through licensing (Gutierrez, 1988). However, the peculiar dynamism of these new sets of institutional social actors, together with the deterioration of the public sector, the reduction of financial resources for research and the lag in the production of innovations, have produced a negative effect upon the national capability to produce an appropriate technological change in the agricultural sector. A fundamental change is required, both qualitative and quantitative, in the nature of the demand of technology for agricultural production, with deep implications for the research system, as much from the point of view of the type of technology to be investigated as from the point of view of the necessary availability of resources and specialists in order to carry it through.

## Conclusions

Science is an activity carried out by individual and group practitioners—the scientists—in specific settings—the laboratories—whose results are communicated to other practitioners like themselves and to other audiences. The Argentine case exemplifies nicely the problems of the transition of knowledge from private to public non-science spaces. Behind the narrative of the process of growth of a scientific community in this developing country, my purpose has been to present historical evidence that suggests how the relationships between science and its audiences can be illuminated by cases of individual scientists and disciplines at different points in time. A variety of experimental, representational and discursive strategies have been shown to be implicated in the creation of a public authority for scientific knowledge. Thus, I have considered how Ameghino managed the transition from his totally marginal position to the leadership of the National Museum of Natural History in Buenos Aires; how Houssay, practically self-taught in experimental science, achieved the maximum consecration of the scientific profession by getting the Nobel Prize while staying in Argentina despite adverse conditions and building an experimental school internationally renowned for its technical quality; or how Sábato, another self-taught scientist, managed to stir the imagination of other scientists and technicians as well as of industrialists and politicians to define a national strategic project such as that of nuclear energy.

Why, independent of their scientific quality, have some of these scientists been successful in their transition to the public stage while others have not? Adler's thesis of intellectual 'guerrillas' offers a possible explanation for some of the cases. He refers to those individual scientists, technologists and economists with authority in domestic and international forums who were able to use state power to mobilize the practical experience of scientific and technological development and its industrial applications. When their views were akin to those of the political elites, they had only to show the way—as in the case of the nuclear industry—shaping collective beliefs and expectations within state institutions and at policy making levels. In other cases, however, their ideological motivations differed from those of the ideological context of ideas indirectly in trying to bring about the desired end by using their technocratic and persuasive skills. More often, they failed to have their ideas carried through. One of the most unfortunate instances of national waste of capacities is that of the relationship of the government with physicist Gaviola.

In general terms, the problem is one of producing a reasonable account of the process of the emergence of a scientific community in a particular society, which enables scientific work to be related to the aims and resources of its practitioners and to the structure of constraints within which it finds itself. All knowledge production comprises an inseparable compound of both types of elements. Precisely what stands out in the Argentine case is the frustrating coexistence of a disproportionate amount of will, imagination, creativeness, and skills and techniques found in individual scientists to probe the natural world, and the unfavourable socio-political factors beyond their control that they encountered as soon as they began to be seen as a menace to the status quo (whatever the domain in question).

## Notes

1. The migration of non-natives was the main component of population growth until 1935, making this city a very special case (Recchini de Lattes, 1971).
2. There were many manifestations of the 'peril' involved in the 'invasion of immigrant students that would later invade society as professionals' competing with those who in the past had dominated professional activity without rivals (see for example, Pueyrredón, in *La Nación*, 1904, as quoted in Halperín, 1962: 118–19).
3. I will show in the next sections that low salaries, continued political and economic instability, and frequent persecution and repression have contributed to the emigration of a good portion of scientists and engineers and discouraged the scientific vocation among the young in recent decades.
4. Yet, since the First World War and particularly since the 1920s, there were clear signals of the exhaustion of a development style which for half a century had relied exclusively on the agricultural rent of the humid pampas. The international 1930s' crisis implied the final demise of that accumulation model.
5. See the papers included in Platt and Di Tella (1985). For other references to Argentine development in comparative perspective see Korol's 1991 review paper.
6. For a recent review of different explanations of the Argentine agricultural stagnation from 1944 to 1960, see Barsky (1988).
7. One of the men that best expressed in his own life the complex tissue of such a dense and invigorating epoch was naturalist E. Holmberg (see Montserrat, 1974).
8. For a description of Gould's activity in Argentina, see Echarri (1970).
9. Ameghino published two works that evidenced his precocious maturity: 'La formacion pampeana' and 'La antigüedad del hombre en el Plata'. In 1882, he organized his ideas about transformation in a conference entitled 'A la memoria de Darwin', and two years later he did the same with his views about the general problem of evolutionism in his *Filogenia* (1884), whose content he defined as the transformist classificatory principles based on natural laws and mathematical proportions (See Ameghino, 1935; Romero, 1965).
10. The Argentine University Reform Movement inspired the leaders of great popular movements in the region, from Haya de la Torre to Fidel Castro, while in Argentina the extra-university repercussion was practically non-existent. Among the historical reasons adduced to explain this is that in Argentina the popular masses had a more complex structure than in the countries where reformist ideas had political success. A good portion of the urban masses with which the students had more direct contact had already found political and union organizations that channelled their interests. Also, different from

most Latin American countries subjected to military dictatorships, in Argentina a democratic experiment had begun in 1916, whose failure was not envisaged yet (Halperín Donghi, 1962).

11. Where, for example, a doctoral degree in chemistry was offered already in 1905 and the Argentine Chemistry Society was founded in 1912, before those of Italy (1919), Canada (1921) and Japan (1948).
12. For his abilities as researcher and teacher, Bose was rapidly promoted as privat-docent and Nernst's assistant. In 1906, he was appointed director of the Danzig Technology Institute, a strategic point to Germanize the eastern parts of Prussia that were Polish-speaking. Precisely that experience was expected to be valuable in Argentina, considered a new cultural frontier to conquer.
13. German influence was not restricted to science. Towards 1909, German officers had reorganized the Argentine army, the Argentine navy came to depend on German wireless technology and German-led firms dominated electric facilities around Buenos Aires (Pyenson, 1984).
14. Among them, the Laboratory of Material Essays of the Ministry of Sanitary Works installed between 1901 and 1903 deserves mention.
15. Later, in 1935, the National Oil Company (YPF) inaugurated in Florencio Varela the most important laboratory of the public sector.
16. For an analysis of the differences between Pan-Americanism and Latin Americanism see Ardao (1986).
17. See Roca and Sanchez's recent book (1990) *Shipwrecked from the Civil War in Argentina* about Terradas and his profitable work at the Engineering Faculty of the Universidad de Buenos Aires, particularly in connection with aeronautical engineering.
18. For an analysis of nationalist thinking in Argentina see Navarro (1968); Zuleta (1975); and Rock (1987).
19. For the story of angiotensin see the papers by Fasciolo and by Page, both published in 1974.
20. Mariscotti, 1985, p. 26.
21. Although in Argentina the term *desarrollismo* took on a political meaning as the label of the Frondizistas, as if Rogelio Frigerio had invented the notion, I prefer to take it in the more general sense of developmentalism, which is often associated directly or indirectly with the ideas of the United Nations Economic Commission for Latin America (CEPAL in Spanish, ECLA in English) and was common for several decades in Latin America. In this sense, as recognized by Prebisch himself, the economic policy content of many of his and CEPAL's ideas and recommendations did not differ substantially from that of the economic policies of the Peronist and Frondizi governments (Sikkink, 1988).
22. Not even CONICET escaped this general trend. Founded on the personal initiative of Houssay, it stressed the natural sciences.
23. For his research on the glandular base of sugar metabolism.
24. The private patron that made possible the creation of the Institute of Biology and Experimental Medicine (IBYME) was a local entrepreneur, Juan Bautista Sauberan, to which was added a substantial contribution by the Rockefeller Foundation and the personal contribution of Braun Menéndez.
25. This time the patron was a textile manufacturer, J. Campomar.
26. See Miller (1950), Box 45.
27. All references to 1956 are from Miller (1956), unless otherwise indicated.
28. Which, like numerical calculus and mathematical logic, became one of the theoretical pillars of the digital computer. See note 13.
29. Madanes was a nationalist and Peronist supporter. This fact helps to explain the difficulties of the firm when the neo-liberal military came to power in 1976.
30. Babini (1991) explains how Humberto Ciancaglini had reached the conclusion by 1957 that the best way to prepare future electronic engineers to master digital techniques was

to start the construction of a computer in the very Department of Electronics at the engineering faculty and the rich set of events that this decision set in motion.

31. (*a*) Radioisotopes (eleven new short-life isotopes discovered), (*b*) analytical division, (*c*) ra technology, (*d*) physics (mass spectroscopy), (*e*) metallurgy, (*f*) biology and medicine—histology, tissue culture, hematology, biochemistry, radiobiology and electron microscopy. Other divisions included (*g*) accelerator division, in operation since 1952 (Cockcroft-Walton, of 1,200,000 volts; Philip's synchrocyclotron, which Ernest Lawrence is said to have told them to be the 'best he had ever seen' [of its class]); (*h*) heavy water separation pilot plant (Miller, 1956).
32. The training programme had the support of many international agencies, among them AIDUS Universities: Texas, Pennsylvania, Michigan; FAO-UNDP; The Ford Foundation; Rockefeller Foundation; CNRS; British Council; and the OAS–Multinational Centres Projects.
33. This school halted its activities in 1976, with the ending of the agreement between the universities and INTA (Trigo et al., 1982).
34. The Ford Foundation contributed significantly to the institutionalization of the social sciences in Argentina. It supported Germany's Instituto de Sociología in the 1950s and 1960s and Instituto Di Tella. By the time of Peronist control of Argentine universities in 1973, active investments in the country totalled some US $2 million.
35. Yet, the big problem remains one of ungovernability, as a consequence of the disproportionate number of unfulfilled demands coming in increasing numbers from civil society and the limited capacity of the economic–political system to respond to them. Posing the problem in these terms, its extreme solutions would be either the forced reduction of demands (authoritarianism) or the improvement of the public services looking for a healthier state and not its dissolution (social democracy).
36. From a financial point of view, the increase in the quality of the teaching staff is always translated in increasing educational costs. Besides, the improvement of teaching requires raising teaching requirements and qualifications, expanding library facilities, guaranteeing an adequate level of non-teaching staff for the correct use of laboratories and equipment, and updating equipment and infrastructure. In conditions of increasingly lower expenditures per teacher, as has occurred in Argentina, none of these requisites to improve the quality of teaching are satisfied.

## References

**Adler, E.** (1987). *The Power of Ideology. The Quest for Technological Autonomy in Argentina and Brazil.* Berkeley: University of California Press.

———. (1988). 'State Institutions, Ideology, and Autonomous Technological Development: Computers and Nuclear Energy in Argentina and Brazil'. *Latin American Research Review*, 23 (2).

**Albornoz, M.** (1989). 'Ciencia y Tecnología en Argentina'. Marco Conceptual y Panorama General. Buenos Aires: Programa de Investigación en Política y Gestión de la Ciencia y la Tecnología, Universidad de Buenos Aires.

**Ameghino, F.** (1935). *Obras Completas y Correspondencia Científica de Florentino Ameghino.* Official edition coordinated by A.J. Torcelli. La Plata: Tallerde Impresiones Oficiales.

**Ardao, A.** (1986). 'Panamericanismo y latinoamericanismo', in L. Zea (ed.). *América Latina en sus ideas.* México: UNESCO-Siglo XXI.

**Azpiazu, D.** (1989). 'La crisis del modelo de desarrollo tradicional y perspectivas para la Argentina', in E. Oteiza (ed.). *Examen de la Política Cientiífica y Tecnológica Nacional. Perspectivas a mediano plazo.* Buenos Aires: SECYT-UNDP Project Arg.87/023.

**Azpiazu, D., E.M. Basualdo** and **H. Notcheff** (1988). *La revolución tecnológica y las políticas hegemónicas. El complejo electrónico en la Argentina.* Buenos Aires: Legasa.

**Babini, J.** (1954). *La evolución del pensamiento cientlfico en la Argentina*. Buenos Aires: La Fragua.

**Babini, N.** (1991). *La informática en la Argentina, 1956–1966*. Buenos Aires: Edicines Letra buena.

**Balán, J.** (1991). *Cuéntame tu vida. Una biografía colectiva del psicoanálisis argentino*. Buenos Aires: Planeta.

**Barsky, O.** (1988). 'Introducción. Reflexiones sobre las interpretaciones de la caída y expansión de la agricultura pampeanam', in O. Barsky, F. Cirio, J.C. del Bello, M. Gutiérrez, N. Huici, E. Jacobs, I. Llovet, R. Martinez Nogueirra, M. Murmis, E. de Obschatko and M. Piñeiro. *La agricultura pampeana. Transformaciones productivas y sociales*. Buenos Aires: FCE/IICA/CISEA.

**Bernaola, O.** and **V. Grünfeld** (1989). 'A Not So Minor Planet: Enrique Gaviola 1900–1989'. Mimeo. Buenos Aires: National Commission of Atomic Energy.

**Bercovich, N.** and **J. Katz** (1990). *Biotecnología y economía política: Estudios del caso argentino*. Buenos Aires: Centro Editor/CEPAL-Buenos Aires.

**Brunner, J.J.** and **A. Barrios** (1987). *Inquisición, mercado y filantropía. Ciencias sociales y autoritarismo en Argentina, Brasil, Chile y Uruguay*. Santiago: FLACSO.

**Cereijido, M.** (1990). *La nuca de Houssay. La ciencia argentina entre* Billiken *y el exilio*. Mexico: Fondo de Cultura Económica.

**Cueto, M.** (1991). 'El Rockefeller Archive Center y la medicina, la ciencia y la agricultura latinoamericanas del siglo veinte: una revisión de fuentes documentales'. *Quipu*, 8(1), 35–50.

———. (1994). 'Laboratory Styles in Argentine Physiology'. *Isis*, 85 (2), 228–46.

**Echarri, A.** (1970). 'B.A. Gould y sus 15 años de trabajo en el Observatorio Astronómico Nacional de Córdoba'. *Boletín de la Academia Nacional de Ciencias*, Córdoba, t.XLVIII, Entregas 1/4.

**Fasciolo, J.C.** (1974). 'The Story of Hypertensin'. *Acta Physiologica Latinoamericana*, 24(5), 391–94.

**Ferrer, A.** (1987). 'Acumulación, cambio tecnológico y deuda externa. El caso argentino'. *Comercio Exterior*, 37(12), 1046–53.

**Foglia, V.G.** (1980). 'The History of Bernado A. Houssay's Research Laboratory Instituto de Biología y Medicina Experimental: The First Twenty Years, 1944–1963'. *Journal of the History of Medicine*, 35, 380–97.

**Gertel, H.R.** (1991). 'Issues and Perspectives for Higher Education in Argentina in the 1990s'. *Higher Education*, 21(1), 63–81.

**Glick, T.** (1982). 'Perspectivas sobre la recepción del darwinismo en el mundo hispano', in M. Hormigón (ed.). *Actas del II Congreso de la Sociedad Española de Historia de las Ciencias*. Madrid: SEHC.

**Gutierrez, M.** (1988). 'Semillas mejoradas: desarrollo industrial e impacto sobre la producción agrícola', in O. Barsky, F. Cirio, J.C. del Bello, M. Gutiérrez, N. Huici, E. Jacobs, I. Llovet, R. Martinez Nogueira, M. Murmis, E. de Obschatko and M. Piñeiro. *La agricultura pampeana. Transformaciones productivas y sociales*. Buenos Aires: FCE/IICA/CISEA.

**Halperín Donghi, T.** (1962). *Historia de la Universidad de Buenos Aires*. Buenos Aires: EUDEBA.

**Instituto de Fisiología** (1941). *Lista de trabajos del instituto de Fisiología de la Facultad de Ciencias Médicas de Buenos Aires realizados durante el perído 1919–1939*. Buenos Aires: Imprenta y Editora Coni.

**Katz, J.** and **B. Kosacoff** (1988). *El sector manufacturero argentino: maduración, retroceso y perspectivas*. Buenos Aires: CEPAL.

Korol. J.C. (1991). 'Argentine Development in Comparative Perspective'. *Latin American Research Review*, 26(3), 201–12.

**Lattes, A.E.** (1986). 'Conclusiones', in A.E. Lattes and E. Oteiza (eds.). *Dinámica migratoria argentina (1955–1984): democratización y retorno de expatriados*. Geneva: UNSRID-CENEP.

**Lattes, A.E.** and **R. Sautu** (1978). 'Inmigración, cambio demográfico y desarrollo industrial en la Argentina'. *Cuadernos del CENEP*, 5, 2–3.

**Mariscotti, M.** (1985). *El secreto atómico de Huemul. Crónica del origen de la energía atómica en la Argentina*. Buenos Aires: Sudamericana/Planeta.

**Mazoti, L.B.** and **J.H. Hunziker** (1976). *Genética—Vol. IV of Evolución de las ciencias en la República Argentina*. Buenos Aires: Sociedad Científica Argentina.

**Miller, H.M.** (1950). *Diary*. 21 December. Tarrytown, NY: Rockefeller Archive Centre.

———. (1956). *Argentine Diary*. October, Box 46. Tarrytown, NY: Rockefeller Archive Centre.

**Montserrat, M.** (1974). 'Holmberg y el darwinismo en Argentina'. *Criterio*, 87 (1702), 591–98.

**Navarro, M.** (1968). *Los nacionalistas*. Buenos Aires.

**Oszlak, O., M. Cavarozzi** and **S. Sonnino** (1982). *El INTI y el desarrollo tecnológico en la industria argentina*. Ottawa: IDRC-MR34s.

**Page, I.H.** (1974). 'The Story of Angiotonin'. *Acta Physiologica Latinoamericana*, 24(5), 395ff.

**Passalacqua, E.H.** (1989). *Argentina: 1983–1988. Crónica de un período*. Mimeo.

**Petitjean, P.** (1989). 'Le Groupement des Universités et Grandes Ecoles de France pour les Relations avec l'Amérique Latine, et la création d'Instituts à Rio, Sao Paulo et Buenos Aires (1907/1940)', in U. D'Ambrosio (ed.). *Anais do Segundo Congresso Latino-Americano de História de Ciencia e da tecnologia*. Sao Paulo: Nova Stella.

———. (1992). 'La coopération France-Amérique Latine'. Paper presented at the Third Latin American Congress for the History of Science, México City, January.

**Platt, D.C.M.** and **Di Tella, G.** (eds.) (1985). *Argentina, Australia, and Canada: Studies in Comparative Development, 1870–1965*. New York: St. Martins Press.

**Pyenson, L.** (1984). 'In partibus infidelium: Imperialist Rivalries and Exact Sciences in Early Twentieth-Century Argentina'. *Quipu, Revista Latinoamericana de Historia de la Ciencias y Tecnologia*, 1(2), 253–304.

**Recchini de Lattes, Z.** (1971). *La población de Buenos Aires; componentes demográficos del crecimiento entre 1855 y 1960*. Buenos Aires: Centro de Invest. Sociales, Instituto Di Tella, Ed. del Inst.

**Roca, Rossel** and **Sanchez, Ron** (1990). *Esteban Terradas. Cinecia y técnia en la Espana contemporánea*. Madrid: Instituto Nacional de Técnica Aeroespacial/Ediciones del Serbal.

**Rock, D.** (1975). *Politics in Argentina, 1890–1930. The Rise and Fall of Radicalism*. Cambridge: Cambridge University Press.

———. (1987). 'Intellectual Precursors of Conservative Nationalism in Argentina, 1900–1927'. *Hispanic American Historical Review*, 67 (2), 271–300.

**Romero, J.L.** (1965). *El desarrollo de las ideas en la sociedad argentina del siglo XX*. Buenos Aires: Fondo de Cultura Económica.

**Sábato, J.** (1973). 'Atomic Energy in Argentina: A Case Study'. *World Development*, 1 (8), 23–38.

———. (1981). *La pampa pródiga: claves de una frustración*. Buenos Aires: CISEA.

**Sábato, J., O. Wortman** and **G. Gargilo** (1978). *Energıa atómica e industria nacional*. Washington, DC: Organization of American States, SG/P.1., FTT/47.

**Sagasti, F.** and **A. Pavez** (1988). 'Ciencia y tecnología en América Latina a principios del siglo XX', in Sagasti et al. *Conocimiento y desarrollo: ensayos sobre ciencia y tecnología*. Lima: GRADE-Mosca Azul.

**Sarlo, B.** (1988). *Una modernidad periférica: Buenos Aires 1920 y 1930*. Buenos Aires: Ediciones Nueva Visión.

**Sikkink, K.** (1988). 'The Influence of Raúl Prebisch on Economic Policy-Making in Argentina, 1950–1962'. *Latin American Research Review*, 23 (2), 128–32.

**Slemenson, M.** (1970). *Emigración de científicos argentinos: organización de un éxodo a América Latina: historia y consecvencias de una crisis politico-universitaria*. Buenos Aires: Instituto Di Tella.

**Solberg, C.E.** (1987). *The Prairies and the Pampas: Agrarian Policy in Canada and Argentina, 1880–1930*, Stanford: Stanford University Press.

**Tedesco, J.C.** (1985). 'La instancia educativa', in H.E. Biagini (ed.). *El movimiento positivista argentino*. Buenos Aires: Editorial de Belgrano.

**Trigo, E., M. Piñeiro** and **J. Ardila** (1982). *Organización de la investigación agropecuaria en América Latina. Reflexiones e instrumentos para su análisis*. San José: IICA.

**Valeiras, J.** (1989). 'Principales instituciones del sector científica y tecnológico', in E. Oteiza (ed.). *Examen de la política científica y tecnológica nacional*. Buenos Aires: SECYT-UNDP Project, ARG.87/023.

**Varsavsky, O.** (1969). *Ciencia, Política y cientificismo*. Buenos Aires: Centro Editor de América Latina.

**Vessuri, H.** (1987). 'The Social Study of Science in Latin America'. *Social Studies of Science*, 17 (3), August, 519–54.

———. (1990). 'El sísifo sureño: las ciencias sociales en la Argentina'. *Quipu*, 7 (2), 149–85.

———. (1991). 'The Argentine Strategy for Latin American Physiology, 1940–1947'. Mimeo. Caracas: Department of Science Studies, Venezuelan Institute of Scientific Research–IVIC.

———. (1992). 'The "Corn Man" from Argentina. The Role of Salomon Horowitz in the Development of Scientific Agriculture in Venezuela'. Paper presented at the Annual Meeting of the Venezuelan Association for the Advancement of Science (AsoVAC), Caracas.

**Zuleta, Alvarez E.** (1975). *El nacionalismo argentino*, 2 vols. Buenos Aires: La Bastilla.

# 12 Growing Pains: Brazilian Scientists and their Shifting Roles

**Antonio Botelho** and **Simon Schwartzman***

For a short period of less than twenty years, between the late 1960s and early 1980s, Brazil developed an unparalleled effort to build its scientific and technological capabilities. This was supposed to make the country economically self-sufficient and develop a significant military presence in the world scenario. Such efforts could have hardly been predicted by Brazil's previous history of scientific and technological development, and the crisis which overtook the whole project since the mid-1980s came also as a surprise. How can one explain this short-lived experience, its origins and consequences? How did it affect the main actors in any effort of scientific and technological development, that is, the scientific community? This is the subject of this article.

## The Golden Age

The ambitions of scientific and technological development in the 1970s can be seen as part of the 'great leap forward' attempted by the Brazilian military regime in those years, which included heavy investments in energy and infrastructure, the development of chemical and machine tools industries, the production of armaments and airplanes, and scientific and technological research in general terms. Some of these initiatives in the latter were:

- The university reform of 1968, with the partial adoption of the American system of graduate education and the re-organization of the universities in terms of institutes, departments and the credit system.
- The placement of S&T under the responsibility of the economic policy authorities, which allowed for a much higher influx of resources to S&T than ever before.
- The creation of a new federal agency for S&T under the Ministry of Planning—the 'Financiadora de Estudos e Projectos' (FINEP)—unencumbered by civil service routines and restrictions, and responsible for the administration of several hundred million dollars for S&T support.

- The establishment of a few large-scale centres for R&D, like the Coordenação dos Programas de Pós-Graduação em Engenharia (COPPE) of the Universidade Federal do Rio de Janeiro (UFRJ) and the Universidade de Campinas (UNICAMP), geared towards technological research and graduate education in engineering and science.
- The beginning of several programmes of military research, such as the space programme and the 'parallel' nuclear programme.
- The agreement with Germany for cooperation in nuclear energy, which was to create an autonomous capability in the construction of nuclear reactors based on locally re-processed fuel.
- The establishment of a policy of a protected market for the computer industry, and later micro-electronics, linked to an emerging national private sector.
- The formulation, by the federal government, of successive national plans for scientific and technological development.
- The establishment of centres for technological research under the main state-owned corporations, which sought to keep up with the technological frontier, develop standards and transfer technology to their main suppliers.
- The strengthening and formidable expansion of the Empresa Brasileria de Pesquisa Agropecuária (EMBRAPA—Brazilian Corporatiion for Agricultural Research), under the Ministry of Agriculture.

By the early 1980s, Brazil had about 10,000 to 15,000 active researchers publishing in the country and abroad, about 1,500 graduate programmes in all fields of knowledge, and a yearly budget for S&T of about US $2 to 4 billion, amounting to between 0.6 and 0.8 per cent of the country's GNP. In 1992, Brazil ranked twentieth among nations indexed in scientific publications, trailing China, Belgium, Israel and Denmark, but ahead of Poland, Finland, Austria, Norway, Taiwan and Korea (Schott, 1993).

It is remarkable that only two decades earlier, when the military came to power in 1964, they entered in direct conflict with a substantial part of the country's intellectuals, including leading academics and scientists. As late as 1971, when some of the projects for scientific and technological development had been launched, dozens of professors and researchers of Brazil's main academic institutions were ousted from their positions, and in many cases they left the country. The military regime was perceived as conservative, submissive to international interests and conveniences, and hostile to the efforts to make Brazil a modern, rational and socially just country—ideals that mobilized most of the country's intellectuals, placing them in a collision course with the military government. To understand what happened in this short period, one should reconstruct the ideologies and motivations that shaped the behaviour and political mobilization of Brazilian scientists in the preceding years.

## The Origins: The Roles of Modern Knowledge[1]

Brazil, until the early nineteenth century, was a colony of Portugal, and because of that was twice remote from the scientific, technological and cultural revolution that swept Europe since the Renaissance. First, because Portugal itself remained a closed country, controlled by a conservative Catholic church, and shut off from the new ideas of religious reform, political liberalism and economic entrepreneurship. After its extraordinary maritime and colonial achievements in the fifteenth and sixteenth centuries, Portugal turned internally to traditional agriculture and became a client state of England, living off the inter-mediation of trade between Europe's more active economies and its colonies. Its largest colony, Brazil, was a source of valued goods in international trade (sugar, gold, wood) and its economy was based on slave labour, first the native 'Indians', and later Black Africans. For a long period, there was no significant European migration to the colony, except Portuguese government officers, tradesmen, persons receiving exceptional land grants and benefits, and Jews or 'New Christians' escaping from the Inquisition. While Spain tried to build its American empire over the pre-Colombian societies they found in America, populating the continent with universities and monasteries, the Portuguese destroyed or expelled the natives to remote regions and allowed only elementary education to be taught to the children of the richest families by the lower clergy.

This dismaying picture began to change early in the nineteenth century, when the Portuguese royal family was forced to come to Brazil under British protection fleeing from the encroachment of Napoleon. With the royal court came the first higher education institutions in law, military sciences and medicine, and later political independence, under the crown of descendants of the Portuguese royal family. Throughout the century, new higher education institutions were organized, the first museums of natural history were created, and the Brazilian emperor himself, Pedro II, was a Maecenas of the arts and sciences in Brazil and abroad. Brazil was one of the first nations to adopt the telephone. Slavery, however, persisted until 1888, together with a plantation economy and large areas populated by the remnants of the boom economies of sugar and gold of the preceding centuries.

It is difficult to talk about science in those years except for a few foreigners hired to manage the country's museums of natural history, the national observatory and, later, the geographical and geological commissions.[2] Their impact in the country was negligible and whatever the value of their scientific contributions, it was directed towards their colleagues and counterparts in Europe or eventually the United States. What Brazil did have, however, was the gradual emergence of a new social group—men educated in the liberal professions of law, medicine and engineering, some of them educated abroad (Stols, 1974). More often than not, they would be the children of traditional families from regions with decaying economies, and would strive to regain status and prestige through the strength of the new knowledge granted to them by their education. For the medical doctors in the nineteenth century, Brazil was a sick country, suffering from lack of hygiene, promiscuous behaviour and bad eating habits. They felt the emerging medical profession should take the responsibility to clean the environment and control sexual and other appetites. Later, a small but significant elite in the medical profession became involved in large sanitation projects that were very effective in controlling some of the contagious diseases that ravaged the cities of Rio de Janeiro, São Paulo and Santos, and in the establishment of Brazil's first scientific institution—the Instituto Oswaldo Cruz—in Rio de Janeiro, inaugurated in 1900 (Stepan, 1976). For others, Brazil's main problem was related to the racial composition of its population. How could one not develop a modern, Western-style society, with a population dominated by Blacks, Indians and all kinds of mixed bloods? Theories about inferior and superior races entered the country and were avidly read and, in the first decades of this century, eugenics emerged as the magic key to the future and was the subject of books, voluntary associations and propaganda (Stepan, 1991). Races were already too mixed and the mores inherited from the Portuguese too permissive to allow for racial apartheid. Some theorists contended, however, that given the superiority of White blood, the Black and Indian races would slowly disappear in the country's melting pot, and the future was guaranteed by this slow whitening of the population. There were, however, tasks to be confronted at once. Criminality, drunkenness, stupidity—all these 'deformations' of character and personality were supposed to be hereditary and apparent in the shape of a person's head and body. To understand these links better, doctors turned to physical anthropology and legal medicine, which became the basis of Brazil's main tradition of anthropological studies. However, the eugenics movement was never strong enough to shape public policies, except perhaps for restrictions to the immigration of Orientals and Jews in the 1920s and 1930s, and after the War it lost all its legitimacy. It is not clear, however, how much of it remained in the perceptions of the country's elites.

For the military and engineers, positivism was the answer. Brazil was poor and underdeveloped because it lacked a government guided by science and concerned with the education of the poor. S&T for the positivists was very different from what was beginning to take place in research laboratories elsewhere—a gradual process of knowledge building through exchange of information, consolidation of experiences, negotiation and consensus building. It was first an ideology to settle professional turf disputes against priests, lawyers and others who did not have proper training in mathematics and the natural sciences. Followers of Auguste Comte created their own religion, with their own 'temples' and 'saints'. Second, it was a re-enactment of the old Platonic notion of government by the philosopher. Knowledge was hierarchical, and those acquainted with its highest level—the new sociology proposed by Comte—were those entitled to rule. Positivists despised universities, perceived them as remnants of the old regime, and did not care about democracy and majority rule. Those who knew more had the right and the responsibility to govern—a task made easier when they were also military men with cannons on their side. The military overturned the Brazilian empire and the inauguration of the Republican period in 1889, and in the next century the military participated in several insurrections and coups d'état—in 1922, 1930, 1937, 1945, 1954, 1961 and 1964—always in the name of their superior training, knowledge and patriotic values.

Two related developments should be mentioned at this point—urban renewal and Marxism. In the late nineteenth century, the old capital of Minas Gerais Province, Ouro Preto, was replaced by a new city, Belo Horizonte, dreamed and planned by engineers, which was to be the beginnings of a new era of rationality and modernization for Brazil fit for the twentieth century (Bomeny, 1991). A few decades later, the old centre of Rio de Janeiro was razed to open the way for wide boulevards and modern buildings, after a period in which government agents entered people's houses searching for sources of mosquitoes and enforcing mandatory smallpox inoculations. In the early twentieth century, Rio de Janeiro witnessed one of the most curious episodes of the country's history—the rebellion against mandatory inoculation—with barricades being raised in the streets against the health authorities and wide support for the upraised population in the press (Murilo de Carvalho, 1987). What existed in common between the urban reformers and the sanitation authorities, and placed them against the urban poor and the newspapers, was the technocratic spirit with which they tried to force society to conform to their notions of health and urban aesthetics.

Socialist and revolutionary ideologies were brought to Brazil by Italians, Spaniards and Jews who landed in Rio de Janeiro at the turn of the century as part of the broad immigration wave that followed the end of slavery. They organized their burial associations, cooperatives and the first trade unions, and held the first strikes in the country's history. In the 1930s, however, the Brazilian Communist Party was taken over by a group of young military officers led by Luís Carlos Prestes, a former army captain, and in 1935 a series of rebellions in military barracks marked a failed attempt to install in Brazil a socialist regime with the active support of the International Communist Organization Comintern (Waack, 1993). In the following decades, this group of young officers remained the core of the Brazilian Communist Party, and it is difficult to tell them apart from their positivist colleagues, except for their alignment with the communist movement. Like the positivists, they believed they had access to superior knowledge, Marxism, and the updated version of Comte's sociology. Their role was to spread the good news, educate the masses to let them see light, and take power by whatever means was available. Like the positivists, they did not care for research and scholarship, since all needed knowledge was already available, and of course had no appreciation for the rules of the democratic game, understood as a farce for the preservation of old oligarchies and the status quo. Were they to take power, they would place the whole economy under scientific management, end exploitation, provide education for everyone, and make Brazil a prosperous and happy country.

Varieties of modern knowledge, thus, helped to shape the ideologies of small, educated groups, coming usually from active or decaying elites, and which led to significant movements of social reform—on hindsight, some more pertinent, others completely misguided, but remaining always extremely elitist. Most of the founding fathers of twentieth century Brazilian science, both in the natural and biological sciences, came out of this ideological matrix.

## The First Scientists and Academics

Brazil's first real university, the Universidade de São Paulo (USP), was inaugurated in 1934, and was the source of most of the research groups that emerged in other parts of the country after that. The creation of this university was the main outcome of a period of scientific and educational activism, when intellectuals, educators and some politicians mobilized to fight illiteracy and build higher education institutions of good quality. Brazil in the 1930s was still predominantly an agrarian society, but very different from the previous century. Massive migration, mainly from Europe and the Middle East, populated the rural areas and the main cities from Rio de Janeiro to the south; a small industrial base had begun to develop in the urban centres, producing food, textiles and other manufactures; while a booming coffee economy brought resources and attracted further migration to the state of São Paulo and neighbouring regions. Politically, the centralized empire of the nineteenth century had been replaced by a decentralized federation of states governed by local, rural-based oligarchies.

Developments in the areas of science and education should be seen in terms of at least three undercurrents that swept the country in those years. The first was the drive for political centralization, led by the military, the positivists and the intellectuals who saw in the authoritarian regimes of Europe the road to modernization and economic development. The second was the persistence of regionalism, which in some cases meant the maintenance of traditional patterns of oligarchical domination, but for the richest regions was related to the demands for autonomy for an active and recent capitalist economy. The third was a drive for social mobility led by the second generation of immigrants and the educated children of the middle classes that lived around the main urban centres, and affected the previous two. In the end, modern Brazil was organized as a shifting balance between these tendencies, as illustrated in Table 12.1. Centralization occurred in 1930, but the autonomy of the more developed regions asserted itself through the years, while the middle classes gradually increased their size and presence in the country's affairs. The cleavage between centralization and decentralization trends appeared as a historical tension between the political elites in Rio de Janeiro and the business and economic elites in São Paulo.[3]

**TABLE 12.1**
**Political Ideologies of Brazilian Elites**

| *Groups* | *Centralization Trends* | *Decentralization Trends* |
|---|---|---|
| Elites | Autocratic Policies | Oligarchic Domination |
| | Technocratic Ideologies | Liberal Ideologies |
| New Middle Sectors | Populist Policies | Participatory Politics |
| | Authoritarian Ideologies | Social Democratic Ideologies |

The movements for science and education in the 1930s were mostly an affair of the elites, and incorporated little of the demands and values of the middle and lower sections of society. In Rio de Janeiro, an ambitious project of a national university hoped to set the standard and the model for the country. Architects from Fascist Italy were invited to plan for a university city, select working groups, meet to define the contents of courses in all areas of knowledge under strict government supervision, and from then on a uniform, coherent educational structure was to evolve.[4] The Second World War and the climate of political democratization that ensued from Brazil's decision to join the allies in the War effort emptied this project of its more authoritarian contents, but this was still the origin of the Universidade do Brazil in Rio de Janeiro (now the UFRJ).

The USP was also a creation of the state's business and political elites, but it was altogether different. There was an explicit intention to form and educate a regional elite which could confront and overcome the autocrats in Rio de Janeiro and the traditional politicians in other states. The new university was to be organized around a group of European scientists invited to form a new Faculty of Philosophy, Science and Letters, which was supposed to provide scientific support to the professional faculties and to educate teachers for secondary schools. Professors were invited because of their academic credentials and, of course, their willingness to come to Brazil in those years. Governments of France and Italy were willing to help in a dispute to establish their influence in the new university. Several dozen professors came, and some remained in Brazil for the rest of their lives.[5]

In a small scale, USP opened the space for a new kind of scientist that did not exist before in Brazil—academic men and women getting prestige and acknowledgement for their efforts and talent, and not from their class of origin or political ambitions. In part, this was because several of the invited professors, and most of those who remained, were relatively young and marginal in their own societies (in many cases Jews fleeing from prejudice and discrimination). In Brazil, they looked for disciples, and found them among the children of immigrants and the growing middle classes. For the first time in Brazil, at USP, women entered academic careers in the natural and social sciences in significant numbers. There was a clear contrast between the perceived roles and social behaviour of academics and intellectuals in the country's two centres, which has been observed in detail for the social sciences but was probably present in other fields of knowledge as well (Miceli, 1989). In the capital Rio, intellectuals sought to produce broad interpretations of the country's history and culture, write for the larger public and maintain an active political role (made easier by their closeness to the restricted circles of the political elite). They were not necessarily less ambitious in São Paulo, but their conditions were different. Power was further away, their social origins did not help, they had a better university to work on, and a much larger pool of students and disciples willing to follow their steps. Thus, they had the chance to develop academic careers and, when they got involved in politics, they often acted more as representatives from the rising social movements than from the regional elites.

## Political Activism and the 'Americanization' of Brazilian S&T: The Post-War Years

We can summarize the preceding discussion by saying that from the nineteenth century onwards Brazilian intellectuals, academics and scientists often shared the Platonic view of their destiny as the saviours of their country through their special and privileged talent and knowledge. As the liberal professions of medicine, engineering and law became larger and more established, they also became more professional, taking care of their special place and privileges in society but slowly abandoning the higher ambitions of dominant power and influence. Scientists, as a smaller latecomer group, may have followed a similar pattern, although at a later time.

The small group of scientists and researchers educated at USP, working in the basic sciences and in the institutes of tropical medicine, agricultural research and a few other locations until the 1930s, got a significant boost in their standing and working conditions after the Second World War. Brazil was persuaded by the American government to join the allies in the War effort, and now it was time to help Brazil to overcome its problem of underdevelopment and backwardness. Brazil's first steel plant, in Volta Redonda near Rio de Janeiro, was built with American support as part of the understanding that led Brazil into the War. During the War years, the Rockefeller Foundation, which had participated for years in the control of tropical diseases in Brazil, started providing leading Brazilian physicists and biologists with fellowships to study in the United States.[6] At the end of Dutra's presidency (1945–1950), Brazil negotiated a plan for economic development with the American government that led to a growing institutional influence of American S&T in Brazil. A centre for education and research in aeronautics was developed in the São José dos Campos, under the coordination of Brazil's air force ministry and in cooperation with American engineers and technicians, which gave rise to the Instituto Tecnológico da Aeronáutica (ITA) and the Centro Tecnológico da Aeronáutica (CTA). Both institutions would play a central role in the development of Brazilian S&T over the following decade.[7] Moreover, ITA renewed the stagnant state of engineering teaching in the country by emphasizing its scientific and research components. In the process, it spawned a new community of engineering researchers who would compete with the more academic scientific community for professional legitimacy and for defining the content and direction of Brazilian research in the decades ahead.

In the mid-1950s, Brazilian war surpluses had vanished, and populist politics reduced the federal and local governments' willingness to support science, while the intensity of American cooperation diminished because of the new priorities of the Cold War. Scientists of all persuasions felt a direct threat to their working conditions, and for the first time got organized in an independent association for self-protection—the Brazilian Association for the Advancement of Sciences (SBPC) (see Botelho, 1990a and b; Fernandes, 1989). SBPC was instrumental in the organization of Brazilian scientists as a pressure group; in intensifying its links with the international scientific community; and in the organization of the National Research Council, moulded on the American National Science Foundation, which was supposed to provide the backbone for Brazil's nuclear programme and became Brazil's main science support agency.

The Americanization of Brazilian S&T caused several fractures in the budding Brazilian scientific community. The Americans were willing to help, but not to meet the more ambitious pretensions of their Brazilian allies and would not let them develop an autonomous nuclear capability. In the early 1950s, a group of high ranking military officers and physicists developed a project to provide Brazil with the complete cycle of nuclear energy production, which would also allow for the development of nuclear weapons. The National Research Council and the Brazilian Centre for Physics Research (CBPF) were organized as part of this strategy. The nuclear project was vetoed by the United States, which eventually convinced Brazil to buy a Westinghouse nuclear power plant fuelled with enriched uranium to be supplied by the US (see Goldenberg, 1978; Cabral, 1986; Goldman, 1986; Adler, 1987). In the following years, Brazilian scientists and intellectuals split between those engaged in the American-led modernization trend and those that resented the limitations placed by this alliance on the country's ambitions for independence and economic growth. Anti-Americanism appeared both as nationalism and as anti-capitalism, and the history of Brazil's Marxism contributed to keeping them blurred.

Brazil experienced a period of rapid industrialization during President Juscelino Kubitschek's administration (1955–1960), creating a sudden demand for modern engineering expertise. Modern engineering professionals seized the opportunity to create new institutions and legitimate themselves, which increasingly pitted them against a fragile scientific community. Professional and institutional turf battles took place throughout the late 1950s and early 1960s. Furthermore, ideological battles criss-crossed both communities of researchers and practitioners. The relative success of Kubitschek's industrialization programme strengthened the power of the engineering community, which also found important allies in the growing economic policy making community and in the increasingly discontent military sector. Brazil's alignment with the United States in the Cold War did not solve its problems of underdevelopment and, in the increasingly polarized climate of the late 1950s and early 1960s, scientists and intellectuals spoke out for the modernization of Brazil's universities, the increase in public support for scientific research, and the evils of the alliance between the country's elites and American economic and military interests. When the moment of confrontation came in 1964, the lines were already drawn and the conflict was unavoidable.

## Political Authoritarianism and Scientific Growth

The conflict between the Brazilian military government and the academic community began at the onset of the military regime in 1964, with arrests of academics and scientists and interventions in some universities. The Universidade de Brasília (UnB), created a few years earlier as the emblematic institution of the social modernization movement, was particularly hit. As an organization, it followed closely the American model of a research university, organized in departments and with a strong scientific component. Ideologically, it was supposed to represent the Brazil of the future, with scientists and academics leading a growing national awareness of the country's social and economic needs and leading the nation towards self-sufficiency and social justice. Repression reached its climax in 1971, when several among the best known Brazilian scientists went into forced or voluntary exile.

This was, however, just one face of an ever contradictory picture. The 1968 university reform legislation generalized graduate education and the department structure in public universities, ending with a French-based tradition of professional chairs considered by the scientists as a central roadblock to the modernization of the universities. The National Bank for Economic Development (BNDE), Brazil's main development bank, created a fund for technological projects in 1968, and a few years later the Ministry of Planning set up FINEP, the main agency for science support for the next decades and started to negotiate the return of some of Brazil's leading scientists to the country. UNICAMP, which would become one of Brazil's leading research universities, was organized in the early 1970s around groups of returning scientists and engineers. In physics, for example, its basis was a small group of physicists then working at Bell Laboratories who were persuaded to come back with the promise of strong support for applied research. An equally ambitious project was the organization of the engineering graduate programme at COPPE in Rio de Janeiro.[8] In 1972, an international comparative survey on education abroad and brain drain showed that Brazil was one of the leading countries in the developing world in its ability to bring back and maintain the students it sent out for graduate education (Glaser, 1978). At the end of the decade, most of the prominent scientists who had left the country in the previous years had returned and had often been reinstated in their previous posts.

An explanation for this apparent contradiction is that ideological radicalization was limited to a faction of the military on the right and to a section of the scientists and academics on the left. Anti-communism and anti-intellectualism were important ideological components of Brazil's military regime, and in the early 1970s they were used to justify the power and influence of the so-called 'intelligence community' of the military involved directly with the repression of urban guerrillas. Their influence in other sectors of government was, however, limited. They had little influence on matters of economic policy, for instance, and in the fields of science and education their role was limited to blacklisting the most outspoken figures of the opposition of eventual benefits and nominations to administrative positions.

For most scientists, the sudden availability of research money and employment opportunities, and the modernity and efficiency of the new S&T agencies and their officers (usually young economists or persons with scientific and technological backgrounds), was enough to dispel the notion that the regime was thoroughly anti-intellectual and anti-scientific. The scientific community had a role to play, which was different from what some of them had imagined in the previous years, but it was important all the same, and they took to it with eagerness. Throughout the military regime, the Brazilian Society for the Advancement of Science continued to castigate the government for its authoritarian policies, and its annual meetings were important occasions when suppressed groups could speak out against the regime under the spotlight of the press. It is indeed telling that these meetings were mostly paid for with government grants and, except on one or two occasions, the government did not attempt to suppress them (Botelho, 1990a).

The main difference between the new and the old roles of the scientific community was the narrow limits of the new situation. In the past, many scientists and intellectuals perceived themselves as leaders of broad social revolutionary movements. The campaigns for university reforms in the 1950s and 1960s were a good illustration of that. The universities were elitist, traditional professions controlled the chairs, they were unconcerned with criticism, not committed to providing solutions to the country's main problems, unable to incorporate modern science, had access limited to the children of the upper classes and were isolated politically. A revolution was needed. It would put scientists at the centre of new institutions, the university gates would be open to all, and political alliances would allow professors and students to work together for the solution of the country's problems. In the 1970s, this view had almost vanished and was replaced by a professional pragmatism tinted with nationalism. The top-down university reform of 1968 was surprisingly close to the demands of the past, but it brought to light the contradictions and tensions which existed unavoidably between mass- and research-based higher education. The political climate did not allow for scientists to keep links with organized political movements, and their opposition to the government would have jeopardized the scientists' recently acquired access to public funds and institutional posts. Thus, political activism was replaced by pragmatism. In their newly perceived roles, the scientists were supposed to modernize the state and the economy, to increase the productivity of industry and agriculture, and build a strong institutional and professional basis for themselves. The military, eventually, would go away, and their role in transforming and modernizing society would become obvious to all. The legacy of the 1950s was however expressed in the technological nationalism that flared up in a few technological projects in the 1970s: computers, micro-electronics, space, airplanes and telecommunications. It served as a mythical element that forged a bridge between the old and the new generation of scientists and technologists, and gave the emerging new community a heroic identity above and beyond its pragmatic aspirations.

## Technological Nationalism and Retrenchment (After 1978)

Alas, *l'age d'or* of scientific and technological development did not last long. From the beginning, there was a tension between the country's economic policies, geared to increasing trade and the attraction of foreign firms and capital to Brazil, and the drive for self-sufficiency and nationalism which was present in a segment of the technological community, both civilian and military. While the economy kept growing, this tension could be accommodated. Already by the mid-1970s, barely a year after the first oil crisis, there were signs of decline in the funding of scientific research. At the end of the decade, external debt ran out of control, inflation intensified and expenditures on S&T which had continued to grow in the second half of the 1970s in the politically stronger mission-oriented state research institutions such as the Airforce Technological Centre (CTA), National Space Research Institute (INPE), National Council of Nuclear Research (CNEN), Brazilian Company for Agricultural Research (EMBRAPA), the Research Centre of Petrobrás (CENPES), Research Centre of Electrobrás (CEPEL) and the R&D Centre of Telebrás (CpqD) in detriment to the broader academic establishment started to be perceived by the economic authorities as a waste of resources. There was also a noticeable shift in the destination of resources towards technological research (Botelho, 1993). The crisis that was gradually growing only got worse after 1985, when the military handed over political power to a civilian government. By then, a closed political system had given way to an over politicized society, where a myriad of scattered interest groups jousted for the spoils of a decadent state and a stagnant economy. The ideal environmental conditions for the emergence of a corporative reaction were all in place: dwindling resources, fragmented leading institutions, administrative instability and competition, lack of a unifying vision and a political vacuum. The direct consequences of this situation were the drastic reduction of resources for S&T and a general feeling of demoralization in the scientific and technological communities. The reaction from the scientific community consisted of an attempt to re-enact two roles of the past—one of the scientist as the leader of economic and political nationalism and the other as a social vanguard.

The best expression of nationalism was the expansion and intensification of the policy of market reserve for the computer industry, which came to include micro-electronics and telecommunications, although it was by no means alone (other examples were the nuclear, space and arms producing programmes). The computer policy brought together the conservative military, the liberal scientists and engineers in a joint effort to build a national computer industry that could resist the invasion of multinational corporations and their proprietary equipment.[9] This alliance proved strong enough to pass a comprehensive law approved by Congress and signed by the last military president in the twilight of his government. The law remained in effect until the early 1990s, but failed to create a critical infrastructure for R&D in computer science and micro-electronics that was to be the backbone of the new policy. It eventually suffered the opposition of economic policy makers and most user groups, from academics to industrialists who were restricted in their ability to get access to state-of-the-art information technologies.

The second role consisted of the organization of scientists, researchers and university professors as interest groups and lobbies concerned with the defence of their special interests. Even the SBPC, which in the past had always combined a public image with a prestigious scientific leadership and a permanent dialogue with the government authorities, strengthened its ties with the syndicates of university professors and civil servants and committed itself to the defence of technological nationalism, which included the remnants of the computer policy, the support for military projects and opposition to the enactment of an internationally accepted patents law. At the professional and institutional levels, corporative organizations engulfed each other in a continuing battle for scarce resources, political visibility and social legitimacy. The professional and political constitutive elements of the identity of the scientific community of the 1970s were shattered.

## The Future

The future of the Brazilian scientific community will partly depend on the country's ability to start over its drive for social modernization and economic development, under the new conditions of the 1990s and after the year AD 2000, and to establish a new identity. After a decade of economic instability, stagnation and high inflation, there is an ongoing discussion about what these new conditions are and what will be needed to respond to them. This discussion will necessarily affect the whole sector of science, technology and education, and influence the attitudes and perceptions of scientists and academics. We can summarize our perspective about the future in three propositions.

First, the motivations, perceptions and mechanisms that had characterized 'the golden age' of the 1970s and which had lingered through the 1980s will not return for several reasons. The growing internationalization of the economy is increasingly incompatible with policies of technological and economic self-sufficiency, and the new international order derived from the end of the Cold War does not justify a concentration of scientific and technological investments in a limited number of military projects. As military security is redefined as economic security, the rationale, methodology and limits for state intervention will change.

Second, it has been realized that a central requirement of a modern economy is an educated population and the spreading of professional, managerial and technical competence throughout society. Brazilian higher education and technical training have been traditionally limited to a small elite, and scientists and technologists have been traditionally more inclined to work at the top—with sophisticated technologies, advanced equipment and high concentration of resources—than at the base of society. This elitism of the scientific and intellectual groups is the counterpart of the country's elitist social culture, and it will not go away easily. Scientists, technologists and academics will continue to lose legitimacy and social support if they do not strive to place their knowledge and competence in the service of society as a whole. The isolation of traditional scientific and academic institutions created opportunities for the emergence of alternate institutions more in tune with local and sectoral realities. Out of 900 higher education institutions in Brazil, 690 are now private institutions. While the quality of education in these establishments is generally low and little research is carried out in them, the unfolding political economy environment may create the right conditions and incentives for them to flourish in new directions.

Third, it is not likely that the government will continue to subsidize academic research and ambitious technological projects if they do not incorporate a well-defined educational, economic or social component. However, as widespread political instability remains, the simple repackaging of old wine in new bottles will continue to be immensely attractive to populist politicians linked to corporative organizations.

Finally, the Brazilian institutional and political framework for S&T development underwent great transformations in the intervening decade. It became far more complex, regionally-oriented and institutionally segmented. At the political level, the traditional financing agencies have largely succumbed to unwieldy bureaucratization and lack of vision. Technocratic efforts to correct this situation through greater centralization and research targeting are blind to the emerging decentralized characteristics of the system and are thus doomed to failure. The mixed results, at best, of the World Bank programmes over the past decade are a testimony to that. Professional segments of the scientific community, in a last corporative gasp to regain an old-fashioned political legitimacy, are betting on big science projects, unaware of the growing mismatch of big science to the international political economy of science and to the domestic societal expectations of the 1990s.

If these propositions are true, then they mean that Brazilian society will still have an important role for its scientists and technologists in the future, but it will be very different from what it has been so far. They would have to definitely give up their Platonic ambition, or the pretence of leading society in the name of their special competence, and become a *primus inter pares* group participating in the reconstruction of new societal projects. They must learn to work in a more cooperative and negotiated context, which will however be more competitive scientifically and stricter in the evaluation of the social costs and benefits of scientific and academic enterprise. They must create new and more flexible links with other sectors of society, and look for resources, support and markets for their services in places beyond the state and large international agencies. It will be a difficult transition, but not an impossible one, and, at the end, the role of the scientific community in the country would be much more in tune with society's needs and aspirations and more legitimized than it has been so far.

The seeds of this transformation are currently budding: vibrant regional S&T networks; the steady growth of R&D in private firms and university–industry truly cooperative projects; a larger diversity of financial support sources; and innovative international and local paths for institution-building. The question remains whether this new system can grow and flower, as the obstacles ahead are multiple. The rapid deterioration of the instrumental and political capacities of the Brazilian state, and the slow and uneven maturing of alternate institutional arrangements at the local level may create a dangerous intermediate situation. Foreign agencies' and federal government experts' visions shaped in a rapidly disappearing era may act as shutters, blocking them from recognizing and priming these promising changes. Continued political and economic instability has created a disenchantment among the new generation of researchers and technologists, who may become reluctant to pursue a new vision for the organization and development of S&T in Brazil. In the end, there is little doubt that the emerging Brazilian scientific community in the 1990s will be more worldly and decentralized, thanks partly to the diffusion of new communication technologies, and more regionally-oriented than its predecessor of the 1970s and 1980s. The demise of the dual hegemony of the central government and of the São Paulo–Rio de Janeiro institutional axis over Brazilian S&T will unleash new and unforeseen tensions, which will ultimately shape the community in the 1990s and beyond.

## Notes

* Alphabetical order.
1. Part of the analysis in this section is drawn from Schwartzman (1991a).
2. For an overview of Brazilian science since the nineteenth century, see Schwartzman (1991b).
3. For a political analysis of this process of social transformation see Schwartzman (1981).
4. For details see Schwartzman (1991b).
5. On the nature and impact of the French contingent see Petitjean (1992). An exploratory account of the German and German-Jew contingents is in Plonski and Plonski (1992).
6. The Rockefeller Foundation had been involved in the development of Brazilian health programmes and medical science since 1917 (see Cueto, 1994).
7. About the creation of ITA, see Botelho (1991). For an analysis of the economic impact of MIT, see Dagnino and Proença (1989).
8. For the creation of UNICAMP and COPPE, see Schwartzman (1991b).
9. There is vast literature on the Brazilian computer policy (see, among others, Botelho, 1987; Evans, 1986; Tigre, 1983; Botelho and Smith, 1985).

## References


**Adler, Emanuel** (1987). *The Power of Ideology—The Quest for Technological Autonomy in Argentina and Brazil.* Berkeley: University of California Press.

**Bomeny, H.** (1991). 'Mineiridade dos Modernistas—A República dos Mineiros'. Doctoral Dissertation. Rio de Janeiro: Instituto Universitário de Pesquisas do Rio de Janeiro.

**Botelho, A.J.J.** (1987). 'Brazil's Independent Computer Strategy'. *Technology Review*, May/June, 37–45.

———. (1990a). 'Struggling to Survive: The Brazilian Society for the Progress of Science (SBPC) and the Authoritarian Regime (1964–1980)'. *Historia Scientiarum*, 38 (Spring), 46–63.

———. (1990b). 'The Professionalization of Brazilian Scientists, the Brazilian Society for the Progress of Science (SBPC) and the State, 1948–60'. *Social Studies of Science*, 20(3), 473–502.

———. (1991). 'The Diffusion of the MIT Model: A First Approach'. Paper presented at 'IIème Atelier Emergence des Communatés Scientifiques en Pays en Developpement', ORSTOM/CREAD, Annaba, Algeria, May. Mimeo. Bondy, France: ORSTOM.

———. (1993). 'Comunidade Científica e Adaptação Política: A Comunidade Ciențía Brasileira e a Transição Democrática', in Maria Eduarda Gonçalves (ed.). *Comunidade Científica e Poder.* Lisboa: FPAEC/Revista Ciência, Tecnologia e Sociedade/Edições 70.

**Botelho, A.J.J.** and **Peter H. Smith** (eds.) (1985). *The Computer Question in Brazil: High Technology in a Developing Society.* Cambridge, Mass.: Massachussetts Institute of Technology, Centre for International Studies.

**Cabral, Regis** (1986). 'The Interaction of Science and Diplomacy—Latin America, the United States and Nuclear Energy, 1945–1955'. PhD Dissertation. Chicago: Department of History, the University of Chicago.

**Cueto, Marcus** (1994). 'Visions of Science and Development: Rockefeller Foundation's Latin American Surveys of the 1920s', in M. Cueto (ed.). *Missionaries of Science: The Rockefeller Foundation and Latin America.* Blomington: Indiana University Press.

**Dagnino, R.** and **D. Proença (Jr.)** (1989). *The Brazilian Aeronautics Industry.* Working Paper 23. Geneva: World Employment Programme Research/ILO.

**Evans, P.** (1986). 'State, Capital and the Transformation of Dependence: The Brazilian Computer Case'. *World Development*, 14 (7), 791–808.

**Fernandes, Ana Maria** (1989). *A Construção da Ciência no Brasil e a SBPC.* Brasília: CNPq/ANPOCS/Editora UnB.

**Glaser, William** (1978). *The Brain Drain—Emigration and Return.* New York: Pergamon Press and Unitar.

**Goldenberg, José** (1978). *Energia nuclear no Brasil: as origens das decisões.* São Paulo: Hucitec.

**Goldman, E.** (1986). 'La Science et la technologie dans la politique nucléaire: une étude de la communatué scientifique brésilienne', in B. Crousse, Jean-Louis Quermone and Luc Rouban (sous la direction de), *Science Politique et Politique de la Science.* Paris: Economica.

**Miceli. Sérgio** (ed.) (1989). *História das ciências sociais no Brasil.* São Paulo: Vértice/Revista dos Tribunais/IDESP.

**Murilo de Carvalho, José** (1987). *Os Bestializados.* Rio de Janeiro: Companhia das Letras.

**Petitjean, P.** (1992). 'Autour de la mission française pour la création de l'Université de São Paulo (1934)', in P. Petitjean, C. Jami and A.M. Moulin (eds.). *Science and Empires.* Dodrecht, The Netherlands: Kluwer Academic Publishers.

**Plonski, R. Saidel** and **G. Plonski** (1992). 'From the Blue Danube to the Sad Tropics: Shaping Modern Science and Technology in Brazil'. Paper presented at the 4th Joint EASST/4S Conference, Göteborg, Sweden, 12–16 August. Mimeo.

**Schott, Thomas** (1993). 'Performance, Specialization and International Integration of Science in Brazil: Changes and Comparisons with Other Latin America and Israel', in S. Schwartzman (ed.). *Science and Technology in Brazil: A New Policy for a Global World.* Rio de Janeiro: Fundação Getúlio Vargas.

**Schwartzman, S.** (1981). *Bases do Autoritarismo Brasileiro.* Rio de Janeiro: Campus.

———. (1991a). 'Changing Roles of New Knowledge', in Peter Wagner, Bjorn Wittrock, Carol Weiss, and Hellmutt Wollman (eds.). *Social Sciences and Modern States.* Cambridge: Cambridge University Press.

———. (1991b). *A Space for Science—The Development of the Scientific Community in Brazil.* Pennsylvania: Pennsylvania State University Press.

**Stepan, N.** (1976). *Beginnings of Brazilian Science—Oswaldo Cruz, Medical Research and Policy, 1890–1920.* New York: Science History Publications.

———. (1991). *The Hour of Eugenics: Race, Gender and Nation in Latin America.* Ithaca: Cornell University Press.

**Stols, E.** (1974). 'Les Étudiants Brésiliens en Belgique (1817–1914)'. *Revista de História,* 25 (100), 653–92.

**Tigre, Paulo B.** (1983). *Technology and Competition in the Brazilian Computer Industry.* New York: St. Martin's Press.

**Waack, W.** (1993). *Camaradas.* São Paulo: Cia. das Letras.

# 13 Science and Production in Venezuela: Two 'Emergencies'

**Rafael Rengifo, Arnoldo Pirela** and **Rigas Arvanitis**

This article attempts to analyze two historical moments in the evolution of Venezuela's scientific community. Both these periods can be summed up by the Spanish word *emergencia*, whose double meaning—emergence and emergency—allows us to draw a path from its origins to the present crises along an elliptical path. Thus, Venezuela's scientific community will be studied at two moments in its history—first, when it emerged, looking at the conditions surrounding its birth; and second, in the present crisis, within a context of changing social 'paradigms'. Thus, this chapter will proceed to analyze the scientific community from its emergence to its state of emergency.[1] One central explanatory theme runs throughout this essay: the link between science and production which constituted a basic and constant desire during the formation of the scientific community, its practices, styles, its world image, as well as in its changing relationships with society.

The chapter is divided into two parts. The first is a brief socio-historical outline of the processes of emergence, institutionalization and crisis which have conformed Venezuela's scientific community. Hence, the intention is to show that since its origins as a community of scientific researchers, local science has been constructed upon a socially, politically, economically, and even culturally, weak basis from which it has tried to grow and multiply.[2] Thus, we would like to show the diverse scientific styles which have been forged in the confrontation between the actors of scientific and technological practice on the one hand, and the social, political and economic space in which they were embedded on the other. In the transcourse of this confrontation, a new important political space was created in Venezuela, namely, that of science policy.

The second part, as will be explained in more detail, is based on two empirical investigations: one on entrepreneurs' attitudes when facing technological change and the other on the main characteristics of the behaviour of Venezuela's scientific community. These investigations demonstrate that the weaknesses inherited from the intermittent and uncertain legitimacy of the scientific community in a context of continuous political uncertainty created a profound paradox, which can only provoke surprise. On the one hand, one observes serious material limitations and a low standard of living for researchers and, on the other, there appears a kind of 'Dutch disease' in science, that is, an abundance of resources far more than are needed that provokes a sort of financial intoxication. By intending to understand this situation, these pages try to contribute to the self-awareness of the local scientific community and to provoke a discussion on current local scientific and technological policy.

## The Emergence of the Scientific Community

### The Conformation of the Actors (1936–1969)

THE SCIENTIFIC COMMUNITY: The bond between science and production is present in the initial discourse of Venezuela's scientific community. From the very beginning and in one way or another it underlies all relationships between the actors in the process. What each one understands as 'science' and 'production' is something we will try to understand throughout this chapter. However, the so-called 'modernization' in Venezuela which appears with the death of the dictator Juan Vicente Gomez in 1936 was always accompanied by the ideal of democratization through 'science as the basis for progress'. In other words, the old, radical and authentic positivist ideal, almost one hundred years later survived as the intellectual model that was used in the development of new institutions and new scientific practices.[3] Elsewhere (see Arvanitis, 1990; Rengifo, 1990), we have explained these simultaneous events: modernization provided the opportunity to create new spaces for scientific practice, especially within the state, bringing together foreign consultants, local professionals and international foundations for agronomy related problems (Arvanitis and Bardini, 1992) or in the struggle against malaria (Gutiérrez, 1992). Those who were guiding the process within the state had been the active opponents of the preceding dictatorship, embodying a democratic ideal.

These first steps led to the constitution and institutionalization of Venezuela's scientific community—a process that can be characterized as being overdue, difficult and incomplete, just as the national development scene has been. Overdue, in relation to the maturity of other regional communities such as Argentina, Brazil and Chile for example; difficult, because its main interlocutors either frequently changed the rules of the game or interfered in the affairs of the academic community; and finally, incomplete, because institutionalization cannot take place without social legitimacy. What has limited the legitimacy of Venezuela's scientific community facing other actors, such as the state, entrepreneurs and society in general, has been the continuous misunderstandings on what science should be for and how it should grow (Rengifo, 1986).

One example can be shown by asking the following question: when can we first speak of a scientific community in Venezuela? Marcel Roche[4] believes that it came into being with the foundation in 1950 of the Asociación Venezolana para el Avance de la Ciencia (AsoVAC), which may be considered as an initial achievement. However, Venezuela's research community was no more than ten individuals during this period (Ardila, 1981). This very small number, however, covered a varied range of professionals who carried out part-time or full-time scientific work such as collecting data and elaborating scientific and experimental analysis along with other tasks, mainly professional ones (such as medicine, agronomy and engineering). These professionals were also active administrators and managers of research as well as practitioners themselves (physicians, engineers or experts). The outstanding figures of science in Venezuela were known as much for their professional activities as for their research activities. In short, they were professionals who carried out 'applied' work and their exclusion is the claim of a rupture within the scientific community.[5] By stating that the scientific community is so small and emerges only in 1950 or after that, a cut is postulated between research and all other 'scientific' activities, that is, activities that use scientific knowledge. Such a cut can only be operated at the very high cost of misunderstanding by the rest of society. It is because such a cut is operated that there appears a need to construct a discourse on 'applied' research.

As Arvanitis (1990) has clearly pointed out, the discourse on 'applied science' with all the burden of confusion, desperation and error is the key to understanding the development of science in Venezuela.[6] Apart from conveying a linear and erroneous image of the process of research, this discourse has obliged scientists to obtain social, political and cultural legitimacy appealing to the usefulness and applicability of scientific effort to resolve national problems. The lack of clarity in this discourse and the diverging positions adopted by scientists contributed to eclipsing the community's attempts to obtain legitimacy. One very illustrative episode has been the opposition of scientists in 1969 when CONICIT was created. 'Academic' scientists opposed the 'applied' scientists, and the former won over the latter both an ideological battle and a political fight, since the more famous 'academic' scientists acquired the governance of CONICIT (Texera, 1983; Rengifo, 1990). 'Applied' scientists were excluded from the governance of the scientific community, a fact that needs to be analyzed in order to understand the rupture which took place, or rather the silent confrontation, between two 'scientific styles'. Table 13.1, extracted from our previous research, summarizes this opposition.[7]

The 'applied' scientists were born within the state framework and they could be considered as an expression of its urgent need to modernize,

TABLE 13.1
Two 'Scientific Styles' of Scientists

| *Applied Scientists* | *Academic Scientists* |
|---|---|
| The subject of science policy is the research team | The subject of science policy is the individual researcher |
| Research priorities are determined by the state | Research priorities are determined by the scientists |
| Applied science should be the first priority | Basic science should be the first priority |
| Research serves the solution of national problems | Research serves the development of science |

which became explosively apparent in 1936: malaria *had* to be eradicated so that oil exploration could take place and the modernization of agriculture could continue. The latter, along with cattle breeding, needed agronomic and veterinary research. All these activities needed expertise on water distribution and use. Thus, these 'experts' were from the beginning legitimate and all they needed was to project their image to the rest of society. In a nutshell, they did not have to justify the 'usefulness' of their knowledge. In contrast to the 'applied' scientists, the 'academic' scientists belonged to a younger generation—the one that came to maturity with the foundation of AsoVAC in 1950—who considered themselves as the country's founders of modern science and all its predecessors as scientific 'forerunners'. Their source of legitimacy was not these professional activities but research itself. Their main aim was to promote the 'ethos' of science (Freites, 1984; Vessuri, 1992). As regards their international links, the 'applied' scientists were very closely linked to the oil companies, the World Health Organization, the Rockefeller Foundation and to various international experts and consultants that visited the country.[8]

The 'academics' for their part had a more tense relationship with the state. This tension was first of all on political matters. In 1950, a new dictatorship, that of Perez Jimenez (1950–1958), closed the universities and relegated a growing number of academics with overseas qualifications either to private professional practice or to autonomous spaces which were created at that moment, such as the Luis Roche Foundation (Roche, 1987). The 'academic' groups were mostly democrats and because of that, after the dictatorship, they were to take command. Again, the link between a social project—modernization—and a political project—democratization—was drawn. But this time, it was not the scientific 'experts' but rather the scientific 'researchers' who were to materialize it.

By contrast to what occurred with the 'applied' scientists, international science did not come to Venezuela as the result of the expertise associated with local public scientists. Rather, new scientific areas began to spring up first in the country due to the action of young researchers who had active links with international science. Thus, the formerly 'applied' work carried out by the state enrolled science (the malaria division of the Ministry of Health or the research division of the Ministry for Agriculture, for instance) was seen by the 'academics' as mere 'modifications' or reproductions of protocols designed by experts or international agencies. Furthermore, academics believed that the administrative tasks associated with 'applied' science influenced research negatively because of a lack of exclusive dedication to research.[9]

These differences are central to an understanding of the weaknesses and obstacles of the local scientific community. With the advent of democracy in 1958, the leaders of the 'academic' scientists, such as De Venanzi, Roche and Garcia Arocha, came to occupy important posts. Their power to summon the community along with their national recognition and prestige made them the creators of the community's most important project since its institutionalization in 1950, that is, the creation of a research council (CONICIT). Throughout the period from 1950 up to the creation of CONICIT in 1969, the arguments of the 'academics' were to clash with those of the 'applied' scientists (see Table 13.1). However, both groups used the motto 'science is the basis for progress' and recognized the need to link science and production. Gradually, the local scientific community was to increasingly identify itself with the themes and priorities of the international scientific system, which was its main source of recognition, and it continued to develop in the midst of constant criticism based on its lack of usefulness.

Ironically, twenty years after the creation of CONICIT, when the division between 'academics' and 'applied' scientists was resolved in favour of the 'academic' scientists, the strategies and arguments which were those of the 'applied' scientists were to surface again in a different political and institutional context.

THE STATE: In the course of the process of emergence of the scientific community, the role of the state has varied. At the end of the Gomez dictatorship (which came to an end in 1936), the opening of the country led to new political and economic sectors, which in turn created a demand for modernization. The Venezuelan state needed specialized knowledge in various fields such as health, agriculture and cattle breeding, transport and administrative organization. It began to modernize education through the creation of institutes, schools and new professional careers.[10]

One probable reason for this intense institutional creation may have been the role of academia. The attitude of the university in this process has been of resistance to change.[11] While the state and local society were pressing for modernization through scientific knowledge, the university maintained its traditional 'aloofness' (Silva Michelena and Sonntag, 1970) by being inaccessible, isolated from society's demands and resistant to change.[12]

Thus, the state has been an essential actor in creating new scientific spaces, even under the dictatorship of Perez Jimenez (1950–1958). While the capacity of scientific expertise within the state grew, there no longer appeared any scandalously urgent areas, such as the sanitary matters of the 1930s. Moreover, the state was able to begin tasks linked to industrialization, modern agriculture and the frontiers of knowledge itself, since the state could count on a technical and administrative infrastructure for its operations. In fact, it then had at its disposal 'translators' which allowed it to identify needs and propose solutions. Ironically, when the first 'science policy' was implemented in 1950, the debate over science and its relevance to society's needs as administered by the state began to disappear.

But it was a 'science policy' with a very special flavour. The modernization promoted by the Venezuelan state (at that moment under the hard rule of dictatorship) was a modernization *sui generis* crystallized in the 'New National Ideal' formulated by the dictator Perez Jimenez, supported by the wealth from oil and aimed at the development of basic industries.[13] Some scientists, like Fernandez Moran, lent themselves to become part of the delirium of the dictator, who in his military megalomania dreamt of atomic weapons, and in exchange of the financing of a nuclear reactor accepted the creation of a research centre on neurology (Ruiz Calderón, 1987). Probably a larger portion of the scientists, many of whom were founders of AsoVAC, became scientific leaders after the late 1950s. They tasted the fruits of international science through their postgraduate studies, understood the significance of state supported science, knew of the Manhattan Project and wanted actively to be part of the feast of science, 'not only eat the rest of the banquet' (as stated by Roche in 1963, cited in ibid.: 251).

In this outline of the 1950s what must be emphasized is the misunderstanding which arose in the dialogue between science and the power structure, the consequences of which are still being felt. This exchange was ambiguous because neither the state was interested in the type of science offered by a small scientific community increasingly oriented to the external world and politically hostile, nor was this community dotted with the political, technical and attitudinal features able to satisfy the state's needs for symbolic and practical knowledge. This mismatch clouded the discussion and its influence was felt when scientific policy got crystallized later on in the formation of CONICIT in 1969.

THE ENTREPRENEURS: Where were the entrepreneurs in this process where science links with production? What role did the actors in-charge of the productive apparatus play? This is not the place to analyze the pattern of national industrialization which would answer these questions. However, an attempt will be made to give a brief answer based on a Weberian type hypothesis and some structuralist explanations as to Venezuela's position in the international division of labour.[14] The conformation of the local elites and their presence in a state with an increasing distributive and productive capacity are the cornerstones of this analysis.

Venezuela's leaders did not include industrialization at the onset in their ideological framework. Thus, arts and crafts and technical applications were considered to be of lesser importance and even disdainful activities in Hispanic–American culture. This disdain for the 'mechanical arts' was certainly not conducive to the creation of a 'Schumpeterian' entrepreneurial spirit, and specially so an industrial spirit.[15] Furthermore, the presence of a very rich state, which distributed quite liberally the wealth gained from oil, encouraged parasitic social conducts to a much greater degree than ever imagined even by Gunder Frank of those who he called, with some irony, the 'lumpen bourgeoisie'.

These two factors together generated a modernization financed by oil without having to pay the cultural and political price for it. This is clearly expressed in the phrase which was coined by Uslar Pietri, 'sowing oil'; it reveals a proposition for an agrarian Venezuela away from industrial chimneys and, more importantly, hostile to a civilization based on technology.[16] Two historical facts serve to reinforce this argument. One being that the Reciprocal Trade Treaty with the United States existed until industrialization was under way in 1970, and was elaborated with the consent of the economically powerful groups even though it mortgaged the possibility of industrialization. The other fact, supported by today's reality, is the enormous number of immigrants in the creation of industry, almost 75 per cent by the end of the 1970s.[17]

An entrepreneurial class with these characteristics, isolated from the image of the 'captains of industry', with inappropriate business skills either due to the absence of a tradition or fragmentation could only be little concerned with the place of scientific and technical knowledge in production. In addition, the economic policy based on an overvalued Bolívar and protectionism completed the picture. In this context, the productive sector's representation to the debate could only be a rhetorical figure. In spite of the sporadic participation of some business personalities, who were typical representatives of the 'phantom' body of national bourgeoisie, they led a movement known as 'Pro-Venezuela'.[18]

## Science, Production and the State (1969–1985)

The historical stage to be evaluated now is that of the institutionalization of the scientific community and science policy. In this period, we observe a plethora of diagnoses, planning, abundant self-criticism and persistence of errors. During these years the science–production relation was given priority in policy studies, public discourse and 'naive' commentaries.

NATIONAL COUNCIL OF SCIENCE AND TECHNOLOGY (CONICIT): THE PLANNING DELIRIUM: The study of this period must be centred around its principal protagonist—CONICIT.[19] The leading role that this institution has played is an indisputable fact, which is unusual in a country where every social initiative is influenced positively or negatively by the logic of the state or its institutions. The first thing to highlight is the genesis of CONICIT as a space for the 'explicit' formulation of science policy. The distinction between explicit and implicit science and technology policy as put forward by Amilkar Herrera has a descriptive relevance here. As it has been stated with little success since 1975,[20] institutional S&T policy in Venezuela was regulated more thoroughly and implicitly by many different government ministries than by the explicit science policy authority, which was CONICIT.[21]

In effect, the Ministry of Education (more than 60 per cent of all research was carried out in public universities), the Ministry of the Economy (which directed industrial and thus technology policy), the Ministry of the Treasury (the public treasury's instruments as well as the tax laws influenced the rhythm of technical change) and, finally the Petroleros de Venezuela, S.A. (PDVSA), the state oil company (its research centre INTEVEP is the research institution with more resources than any other in the country), all in varying ways directed the S&T policy. Moreover, PDVSA and the Corporación Venezolana de Guayana (CVG), another state holding which controls the steel, aluminium and electricity sectors, together managed industries which generated around three-quarters of the GNP, and yet none of their policies, not even those with a very explicit science or technological content, had anything to do with the policies and even less with the opinion of CONICIT.[22]

By the ennd of the 1960s, the country's first diagnosis related to science was made by Gasparini (1969). Some results can be recalled: a minimum of 1,629 and a maximum of 2,109 people declared that they were researchers, but only between 549 and 711 of these researchers had published at least two publications and 41 per cent belonged to the 'hard' sciences, 31 per cent to the social sciences and the rest were scattered throughout the humanities.[23] In addition, Gasparini showed there existed a role tension or latent conflict which appeared to be the expression of the lack of recognition and legitimacy suffered by the local scientific community. The ambiguous discourse in relation to the usefulness of science already mentioned produced this role tension because the role itself (research) had no 'social density'.[24] It is this small scientific community, led by such great men as De Venanzi and Roche, which tried to convince the executive of the need for an autonomous research council to be controlled by the research community, and whose role would be to administer and not plan. The council eventually did emerge and could be described, as far as its 'science' policy was concerned, as a 'petty cash box' for science but with a lot of money. Such an omnipresent state as the Venezuelan one could not accept such an extreme laissez-faire proposition from the scientific community, even less so when it was campaigning to centralize its power and resources. Moreover, within the very public administration itself, in the Ministry of the Economy, the 'applied' scientists could be heard lobbying for a useful science, 'really really useful' under state control. So there was an urgent need to define a technology policy. But the lack of entrepreneurs in the debate, the lack of importance granted to knowledge in production and, furthermore, the non-selective importation of technological solutions against the choice of 'alternative' technologies or the construction of the country's own technological capacity all conspired against the definition of a technology policy (Avalos, 1984).

The concern for technology, beyond the inevitable adaptations of processes and products to local conditions, was not more than either a rhetorical stance, a symbol of modernity of every respectable company, or an individual effort by some entrepreneurs in specific sectors who demanded technology on a daily basis almost going against the current of local industry. In this context, entrepreneurial participation in the design of CONICIT was a personal adventure achieved by industrialists who can easily be named and who were concerned about the future of the country.

CONICIT emerged as an interesting offspring of these diverging projects, but with one element which initially was the cause for 'terror' among the scientific community and which later on would produce 'noise' in the communication between the different actors, that is, CONICIT's planning role. Just like the Greek gods or Feurerbach's god, CONICIT freed itself from its creators, acquiring the status of an independent social actor, or in philosophical language it alienated itself.[25] The planning capacity had an objective of its own: 'non dependent technological development', 'self-reliance' and other similar maxims appealing to the need for a useful science and for applied research.

To understand this situation better, a comparison related to radio will be employed (Pirela, Rengifo and Arvanitis, 1991; Pirela, Rengifo, Arvanitis and Mercado, 1991). The relationship between science and the productive apparatus in Venezuela is analogous to that between FM and AM radio frequencies: independently of whether their broadcasts coincide or not, the researchers transmit and receive in FM, while the firms do the same in AM. These are two incompatible frequencies because they represent different practices performed by diverse social actors in a locus which is equally dissimilar, while simultaneously each participant relies on different financial sources (Pirela, Rengifo, Arvanitis and Mercado, 1991). As was stated at the beginning of this article, the differences must be made clear before the similarities are highlighted. And there are a lot of differences between those who value knowledge and those who understand value; both represent distinct cultural codes (Rengifo, 1990).

Progressive autonomy as regards CONICIT was a process where the institution began to formulate its objectives in a way different than was dealt with either by the scientists or the 'productive' sector. In terms of the comparison with radio, the planning body tried to make everyone transmit on only one frequency in an attempt to create a type of powerful meta-frequency. The result has been the emergence of another frequency, a type of short wave which does not coincide with either FM or AM but produces its own 'noise' which recurrently 'pollutes' the atmosphere.[26] The abundance of laborious and seemingly useless plans of S&T appeared in their maximum expression at the end of the 1970s. It is not surprising that Antonorsi and Avalos concluded their overview of the planning of S&T with the suggestion: 'Planning cannot, at least now, be total and global. It cannot even be ambitious. It has to be full of Franciscan humility and tend toward the concentration of effort . . . in specific exercises' (Antonorsi-Blaco and Avalos, 1980: 174).

THE 'REAL COUNTRY': Far away from the paper moving bureaucracy, in the period we examine (1969–1989), the 'real country' is significant from what could be labelled the 'easy' import-substitution model. In spite of Venezuela's exceptional circumstances of being an oil producing country with a semi-open economy (Mommer, 1987, 1989), its over-protected industry selling in captive markets soon weakened. The option of producing capital goods arose, with its need to pass through more complex phases of the industrial process incorporating greater local added value through vertical integration of companies and, for the first time, to explicitly pay more attention to the issue of technology. This process expanded in the mid-1970s in the midst of contradictions resulting from the crisis of the world industrial model and the simultaneous three-fold increase of oil income. The 'crisis' was to act as a 'catalyst' for concern about technology affecting some industrialists and the state, as shown by the creation of the Council for the Development of the Capital Goods Industry (CONDIBIECA) and the Technology Direction in the Ministry of the Economy.

A detailed revision of this period is however not necessary and only some relevant points will be mentioned. The main aim of these policies and the concern of industry were geared towards the negotiation of technology. Topics such as the diffusion of information on alternative technologies, the necessary disaggregation of technological packages, the avoidance of restrictive clauses in technology contracts, the licensing of trademarks and patents and the strict regulation of foreign investment became the major issues of discussion. These concerns can be summed up in this way: control over the demand for foreign technology and orientation towards local supply. This scheme, although it seemed reasonable, never worked for several reasons. One of the reasons is that precisely in the 1970s there appeared the first signs of a distinct techno-economic model (Pérez, 1985).[27]

New technologies such as micro-electronics and informatics, biotechnology, new materials, and alternative energy sources made their first industrial appearance at that moment. Industry was facing emergent globalization, the changing structure of costs and new forms of organizing production (flexible production scales, 'Toyotism' or Japanese style management of labour and production, total quality control). Knowledge intensive industries became more widespread. To all this must be added the ideological crises due to the advance of a postmodern culture, the plummeting of socialist models and the consequent adaptations of the world system and, particularly in Latin America, the onerous foreign debt. The chain reaction which this new wave of innovations caused along with social imbalances evinced the faint attempts made by the state to link research and production. Nobody really attempted to formalize a policy that would go beyond the 'linking' of university with the productive sector. This is because nobody really had a proper diagnostic analysis of what was going on in industry and what types of activities the firms developed in their laboratories and R&D units. Some of these issues are discussed in the next section.

Among some sociologists, the firm and the entrepreneur became an object of study and of political action because they were the spaces of technological change. But still, discourse was more on applied research and its linkage to the firms rather than the advent of 'technological research', the learning processes, the emergence of hybrid areas of academic research under the interests of industry, or the network model brought about in the context of rapidly changing technology.[28]

## The Open Economy Model: Technology becomes Fashionable

The collection of new policies initiated in 1989, popularly known as 'the package', was implemented in the midst of so many and varied planetary transformations taking place so vertiginously that Lampedusa's phrase is involuntarily brought to mind: everything changes so that everything stays the same. So this part of our text is 'fragile' and rather fragmentary, even more than what should be the norm for social sciences.[29] The fact is that from 1989 the first steps towards constituting an open economy were taken. The following text of Avalos (1991: 32) is an extract which can be deemed as the best 'provisional interpretation' that is available so far till the end of 1991 in Venezuela.

> In synthesis, what is implemented in Venezuela is a market economy, as open as possible, so that the country can efficiently and advantageously

> be inserted in the process of economic globalization. Lack of state intervention, privatization, deregulation, competitiveness, exports, trade reforms, are key aspects of the scheme, and are part of the first transformations which have taken place . . . . I would say that certain extreme positions are being adopted due to the desire to break all links with the past; I hope that soon we will be again able to speak of subsidies and social justice without having to be labelled enemies of the market economy and of productivity. I would also say that we are trying to go too fast without taking into account the doses of change which our productive structures can take. This last point is especially relevant . . . technological development, the corner-stone of the reforms to be implemented, is a question of time, of a long time, if we take into account our starting point.
>
> In spite of what I have just stated, I admit that we couldn't keep going on as before and that the country is generally headed in the right direction given in its own circumstances and especially those which the world is experiencing which were outlined, if I may be allowed to oversimplify, in the meetings of the GATT. The new rules of the game have been laid down and they must be known, interpreted and managed. In other words we must learn to play the economic game according to their rules and obtain the greatest benefit possible.

As we said, technology is now the main interest of the policies of the state. Technology management, initiatives for research–firm links, and prospective technology are all priority issues in CONICIT's discourse. We insist on saying discourse, because despite good intentions this institution does not have any real impact in either the productive plant or at the decision levels where industrial policy is designed. So it will still have to forge a discourse on the usefulness of science, very far from the practice of using science. Moreover, the science policy of the state and the everyday functioning of the scientific community will create a rather paradoxical situation: the scientific community is going to live the coming years between the boundaries of bare survival and financial intoxication. And the struggle to escape from the former and take part in the latter may be complicated and risky since the rules are still not well known. In effect, one of the results of the open economy has been that the state has sold a great deal of assets in public firms. This money is in part reversed to CONICIT. Moreover, a great deal of new technology programmes with support from the Inter American Bank (a project financing bank as the World Bank) are still in operation. Thus, there are large amounts of money that can be oriented towards projects, while at the same time the normal budgetary size seems grossly insufficient for reasons that have more to do with the accumulated deterioration of the financial situation and infrastructure of the universities.

Away from CONICIT, and as a consequence of the opening of the economy, technology has acquired some spaces where an efficient linkage between science and production could arise: among others, the Technological Innovation Fund (FINTEC), the Council for the Development of the Capital Goods Industry (CONDIBIECA) and the Metal-Mechanics Industry Fund for Productivity (FIM-Productividad), in addition to the universities which have created linkage structures with business. Unfortunately, a dogmatic interpretation of what has been called 'Reaganomics' says that 'winners should not be picked' so that market mechanisms can function alone. Thus, although funds exist, there is no real demand for them. One of these funds has already disappeared (FINTEC).[30] Using the now more commonly used expression, what has failed is the lack not so much of an S&T policy (either explicit or implicit), but rather the inoperativeness of the national system of innovation.[31] In defence of the Venezuelan authorities in policy decisions, one could mention that this field of policy is rather new, even in the OECD countries (see OECD, 1992b). It is across this shifting scenario that Venezuela's scientific community is shifting. The administrative and political crisis in the leading universities, which has dragged on since 1985, continues to still bother the community. The deterioration in the income level of researchers as well as other sections of the middle class is indeed a problem for retaining good researchers as in other Latin American countries. What bearings do these problems have on the scientific community? How has this community responded to the deterioration of both its working conditions as well as the personal income of researchers? To answer this is to account for the present phase, where we can apply the second meaning of the Spanish word *emergencia*, that is, emergency.

## The Scientific Community in an 'Emergency'

Since the beginning of our research on the ties between science and production we have used a metaphor that, perhaps because of its extreme nature, has helped us clarify the question at hand: we spoke of that link as a 'marriage'.[32] The metaphor, in addition, alludes to the fact that beyond the obvious difficulties, obstacles, constraints and possibilities, there exist other actors surrounding the 'couple' who, although not always, can generate a variety of conflicts. To explore the present tensions the Venezuelan scientific community is experiencing, we shall make use of two empirical studies which were carried out by our research team as the main sources of analysis. Hence, we shall speak of concrete companies and of concrete research groups. More specifically, we are going to discuss the topic of the relationships between the research capacity of universities, which account for around 70 per cent of the research conducted in the country, and the real demand created by production units. By looking at how the 'marriage' has been 'consummated', we shall attempt to understand why only a 'platonic' relationship has prospered.

## Enterprises and Entrepreneurs: The Process of Technological Learning

There is very little empirical research on the technological reality of Venezuela's industry. Probably, our research on the chemical and professional electronics sectors is one of the very few research studies that presents a radiograph of the behaviour of this pole of the relationship that concerns us.[33] Table 13.2 summarizes the responses given by business people from the chemical sector, which is the most highly developed from the standpoint of technology. These responses emerge from a questionnaire we administered to 119 companies in the chemical sector. The table 13.2 shows the responses given to questions on various activities where the company has experience:

**TABLE 13.2**
**Technological Learning in Sampled Firms**

| *Technological Learning* | *No.* | *Percentage* |
|---|---|---|
| Search for specialized information on technological alternatives | 83 | 69.6 |
| Technology negotiation | 63 | 52.9 |
| Development of new products | 98 | 82.3 |
| Machinery and equipment adjustment and alterations | 72 | 60.5 |
| Self-manufacturing of parts and equipment | 56 | 47.1 |
| Process design | 57 | 47.9 |

**Note:** For a detailed description of each activity see Pirela, Rengifo, Arvanitis and Mercado (1993).

This data, as well as those from the technical relationships that the firms are engaged in; the licensing activity; their internal technical activities such as engineering; types of quality control; and R&D were used to construct a taxonomy of this industry. It tells us that close to 66 per cent of the companies have learned to handle the technology they have acquired, not only by adapting technologies but also by genuinely introducing changes in products and processes in order to respond to a particularly restricted market. Thus, these companies have constructed a certain 'flexible' production capability, very consistent with the global trends in the chemical sector. The trend is towards small production units or small specialized productions oriented towards specific demands. The constraints these firms have to face lie more in raising the level of specialization and sophistication of the products they manufacture, which entails strengthening the ability to innovate products rather than 'trouble shooting'.

Another group of companies (34 per cent), mostly small, quite isolated and many of which are monoproducers, have concentrated their attention on adaptations and modifications of spare parts and machines, and on the manufacturing of equipment and parts itself. Similarly, they show only little experience in the other steps of technological learning and a weak capacity, particularly in developing products and designing processes. Hence, an important part of the experience these establishments develop in this field is not only in a certain sense inconsequential for a competition minded company in the chemical sector, but, in addition, the work they do fails to generate a true technological learning since they lack structures allowing them to build a memory capable of projecting the momentary activity towards the future. In some cases, we found that we were dealing with companies that import or buy a product on the local market and then package it directly or after making a simple mixture. The technical activity of these companies is aimed basically at 'trouble shooting' and at corrective maintenance with little effort to innovate.

In addition, a factorial analysis permitted the identification of four characteristic profiles of the behaviour of business vis-à-vis technology (Pirela, Rengifo, Arvanitis and Mercado, 1991, 1993). Only one of these, which were present here, has established any noteworthy link with the academic sector. We call this group 'active companies'. It includes twenty-eight of the 119 companies analyzed, which represent, to differing degrees, the 'cream of the crop' of Venezuela's chemical industry. Most companies are located in the basic or intermediate sectors and, it should be noted, include the presence of a large number of companies devoted to the production of resins.

These companies' external technical links are rather broad and complete, especially for the development of new products for which purpose they establish ties in nearly equal proportions with universities and domestic or foreign firms (62, 65 and 57 per cent respectively). Regarding processes, they prefer to establish ties with foreign or domestic firms (42 and 58 per cent respectively), and almost none (8 per cent) have links with universities for this particular task. For equipment manufacturing they prefer, to a significant degree, domestic firms (85 per cent) over foreign firms (38 per cent), and none prefer universities. Technical assistance is realized mainly through foreign firms first, then domestic firms, and finally universities (65, 42 and 23 per cent respectively). A surprisingly high proportion (89 per cent) of these firms have had some contact with universities or domestic research centres even though this may not be a research contact.[34]

Some uncommon or unexpected facts observed in the study deserve mention here. None of the four profiles of firm behaviour vis-à-vis technology show significant differences in economic results. Briefly put, somehow provocatively, we found little relation between economic variables and technological variables prior to the economic policy of economic 'aperture' in 1989. In the context of highly protected markets, economic efficiency is not the central motivation for dealing with technological problems, except those that could hamper companies from continuing to produce. The key problem is that Venezuelan firms (this is a trait observed in nearly all sectors [Pirela, 1984]) have operated in a wide range of markets where the degree of competition is low with essentially monopolistic structures and highly protected from foreign competition. Indeed, in our survey the response to competition as an influential factor for introducing innovations is, in general, unimportant. In reality, the competition factor has exercised less pressure on firms than the difficulties to obtain raw materials, the needs stemming from the diversification of production or from the needs to meet customers' requirements. In addition, the competition factor has the same weight as that of satisfying the aim of a personal or professional challenge. To continue with our metaphor of the relationship between the university and firms, we can say that some firms were preparing for the 'wedding'.

## Academics and Academia

As dealt with in the preceding section, we shall present a summary of an empirical analysis of data gathered through a survey directed at researchers.[35] This survey tried to evaluate the socio-economic context and the 'labour' situation of researchers (job satisfaction, workplace efficiency, and so on), the amount of time that researchers devoted to activities directly related to the production sector, the attitudes of researchers towards industry, and the flow of researchers from research centres and universities towards industry (the 'internal' brain drain).[36]

THE SURVIVAL OF THE SCIENTIFIC COMMUNITY IS BEING THREATENED: The average level of seniority or the average number of years of experience in research increased considerably between 1983 and 1991. Whereas the average age increased by 2.5 years, the average number of years of seniority increased by nearly four years. This disparity is explained by the 'brain drain' phenomenon, both to domestic industry and to other countries, and by the absence of a renewal of researchers. Among the older researchers, only the most experienced remained in research. This clearly indicates the relative absence of a good recreation system or the rapid dropout of professionals who are being trained. Indeed, in the last three years, approximately 20 per cent of the researchers in the various research centres where surveys were conducted had left, either to join industry or go abroad.

All available evidence indicates that the effects of this phenomenon had not been fully understood. The opinions expressed ranged from alarm in the face of the danger of a possible annihilation of the scientific community (expressed by the core of the community itself and from its union or political representatives) to the satisfaction expressed by many business people who have found in universities and research centres a 'reservoir' of highly skilled labour which is often cheaper than the professionals they had earlier imported from abroad at a relatively high cost. It may be pointed out that until the Bolívar was devalued in 1984, many companies with a certain formal structure or interest in R&D had a policy of hiring staff from abroad. The issue is, however, more complex. It may also be pointed out that the mobility of researchers towards domestic industry is not by all means necessarily a negative factor. On the contrary, this might contribute significantly to the creation and strengthening of a local capacity for R&D in industry itself, which is an essential condition for the true construction of an integrated system of innovation.[37]

After acquiring a certain degree of experience, to make a transition 'free of traumas' to industry by the researchers can benefit the institutions they leave in some ways: (*a*) these people renew their research fields consistently with the changes in productive knowledge; (*b*) the institution enhances its links with industry, insofar as the persons who leave contribute to that linkage; and (*c*) the constant turnover of personnel allows the natural inter-personal and inter-group tensions, frequent in academic centres, to be mitigated temporarily. At the same time, this inhibits the formation of informal structures or of internal pressure groups, the so-called cliques, and their deleterious effects on the performance of research centres.

We know that the model that has been described in the preceding paragraphs holds only if an adequate flow of incoming researchers is guaranteed, to avoid the total dismantling of the R&D capability in universities and other research centres. If the constant training of upcoming generations is not guaranteed, there emerges a trend towards institutional aging, deterioration in the quality of research projects, and, above all, delays in research fields, topics and proposals due to the departure of 'the best' or those in highest demand by industry. In addition, this translates into universities and research centres increasing their degree of isolation from society and its needs; increasing bureaucratization, backwardness and mediocrity; a lack of dynamism; a deterioration in the internal atmosphere; inter-personal and inter-group conflicts; as well as an unhealthy dynamic, characterized by the presence of groups whose main objective is to pursue internal positions of power 'at any cost'. This clearly leads to an increasingly high degree of deterioration in the institutions. This phenomenon becomes considerably worse in periods of political and administrative crisis in universities and, particularly, in periods of rapid erosion of the purchasing power of university professors' salaries, as has been the case in Venezuela in recent years.

THE INSTITUTIONAL CRISIS: A second problem is related to the decline of the identity of researchers with the institutions themselves. Among the most serious problems that can face an organization is when its members cease to identify with it, and in some cases this can even translate into a feeling of isolation and alienation vis-à-vis the institution. The results that emerge from our survey provide potentially alarming evidence of what may be a 'dangerous' deterioration of the identification of the scientific community vis-à-vis the institutions to which they belong, mainly the university settings.

Forty-one per cent of the respondents felt that the decision to join industry from the academic setting is favourable or very favourable. At the same time, an overwhelming (89 per cent) felt that the decision is unfvourable for the institution of origin. Among the reasons which led the researchers to take a decision to leave their research institution and work for industry are (in their order of importance): the high cost of living, better working conditions elsewhere, the lack of recognition and of promotional avenues in universities, the lack of resources for research, the lack of support from the university institution, deterioration of the university environment, the low degree of support for research work, and, lastly, only 4 per cent mentioned the low research budgets at universities. From their standpoint, the problem has more to do with the economic context, with administrative structures and with political problems than with mere budget concerns. This indicates that the traditional image, disseminated by university spokespersons, according to which the most important problem of these institutions is low budgets is not an argument with which researchers identify.

Moreover, although 68 per cent of the respondents indicated they were satisfied with their work, nearly all said this was due to the freedom they have to carry out their activities. In addition, those who indicated they were dissatisfied attributed this to deficient working conditions, to political sectarianism and to the 'bureaucracy'. Sixty per cent complained of the 'lack of material rewards for the efficient development of research activities'. In addition, only 19 percent said that 'the institution provides them with clear goals in research and development'. Thus, the most important factor for researchers' satisfaction is absolute freedom, that is, ability of the institution to define objectives and goals. In some sense, those inside the universities stay there because they feel very little constraint and at the same time very little identification with the institution.

THE PERCEPTION OF THE MARKET: It has been pointed out many times how researchers work on themes unrelated to the country's needs and industry's potentials. More precisely, this is a common sense perception, the reality being that researchers choose their subjects on themes that are related to the *country's* needs but not to *industry's* needs. Although 41 per cent stated that when a research problem is chosen they do not have in mind the potential utility of the results for the production of goods and services; however, this is higher among science-oriented researchers (58 per cent) than among technology-oriented researchers (only 16 per cent). Nearly all our respondents knew which industries could use their results: 42 per cent mentioned the petroleum, petrochemicals and chemical substances; 10 per cent the steel and metal industries; and 8 per cent the coal industry. This corresponds not only to a rough rating of the importance of the various industrial sectors in the country but mainly of those industries that have developed a real technical dominion and have the capacity to absorb research findings. As we have shown elsewhere (Pirela, Arvanitis, Rengifo and Mercado, 1992), it is only when a company has built an R&D capacity of its own can it integrate, assimilate or transfer research findings produced in universities and research centres.[38] Thus, researchers have a relatively exact sense of who could be the main users of scientific knowledge in their country and are better informed than the policy imperatives suggest.

THE CHANGING VALUES: THE FOUNDATIONS OF A SOLID ECONOMIC LEGITIMIZATION: The scientific community we examined is in a process of transition from professional science to the professionalization of science, that is, from 'conducting good science' (which has been the objective of the founders of that community) to what is presently an unavoidable challenge in the light of global transformations, in particular, in the context of Venezuela's recent process of economic opening.[39] Although the academic community itself appears to be accommodating to these changes, institutions stand out for their backwardness and operations according to the old models. Hence, some such institutions are standing in the way of the connectivity of the scientific community with the rest of society.

As far as researchers are concerned, we have observed that they now accept a change of values. They accept that knowledge is not 'free' information and that they have to receive some reward for working with industries. Thus, they depart from the old vision that implied that the country was to receive the philanthropic aid of the researchers. Giving a price to scientific activity is, as our sampled researchers suggest, a way of giving value to science for the country. Thus, researchers move from a world of 'barter' to a world of 'exchange' (Pirela and Rengifo, 1991). Exchange does not necessarily mean market exchange, but it does mean monetary exchange. Thus, institutions need to change in order to permit these continuous flows between academia and the productive sector. The problem lies in accepting the basic asymmetry between research and technological development. Beyond the differences of context between the two domains, the internal and external determinants of the two activities—epistemological, methodological and those related to the organization of labour—imply new institutional spaces which could handle some complex situations provoked by issues such as that of industrial secrecy, the payment of royalties, rewards for consultancy, legal frameworks for university–firm contracts and so on. To surpass these obstacles, political, institutional and legal forums must be created to act as translators of the diversities of these two 'worlds'. Hence, the development of a common technological 'culture' can serve as an axis between these forums: the point of departure to overcome the asymmetries might lie in the generation of a productive experience in the research centres (university companies might be one solution) and of research structures in firms, and between the two, instruments and structures aimed at developing shared, specialized information systems.

## Conclusion

In sum, until now Venezuelan firms were not interested in developing ties with universities because they lacked a technological capability of their own, and a structure and an internal research capacity able to identify their needs. On the other hand, the academic sector had little to offer, given the behaviour of the institutions in which academics work and, especially, given the way scientists valued their own contribution to development. The state set out to try to convince both sides, creating a third forum for interests which had little to do with either the scientists or the firms. The 'marriage' could not work since the parties were not in 'love'—and in some cases may have been guilty of 'bigamy' given their relations with the foreign world—or 'loved' only platonically. This affair worked even less when a third party, a self-serving 'cicerone', spent too much time trying to demonstrate the wonders of a possible wedding. In any event, experience indicates that at least with the matter at hand the idea is not to 'marry' but rather to construct a modern, 'systematic relationship', with autonomy for both parties and free of 'guardians'.

Finally, a modern link such as the one we have outlined would allow the risks noted a few pages earlier, such as survival on the verge of disappearance, the distortion of scientific work and the intoxication of funds without clear policies or without any insertion structures, to be averted, at least partially. Thus, the legitimization that has been postponed, or mistakenly constructed, must give way to a contemporary relationship with society.

## Notes

1. This analysis is based on work developed in the Department of Science and Technology in the Central University of Venezuela (CENDES). The empirical research on scientists and firms was carried out by our group in collaboration with the Department.

2. This part is based on the work presented at the first ALFONSO workshop (see Rengifo, 1990). It re-interprets the abundant literature on the history and sociology of science in Venezuela. It, however, follows the seminal work developed by Díaz et al., 1983; Vessuri, 1984, 1987a.
3. See, for instance, the 'Plan de Febrero' of General López Contreras who followed Juan Vincente Gómez in 1936 (Ruiz Calderón, 1992a) or the anti-malaria campaigns (Gutiérrez, 1992). For a review of the profusion of scientific institutions created between 1936 and 1948 see Freites and Texera (1992).
4. Marcel Roche, a doctor and researcher in bio-medicine, was the founder of a research institution in the 1950s, first director of the Institute for Basic Science (IVIC) after 1958, and founding member of the National Commission for Science and Technology (CONICIT).
5. Many examples can be given. On botanics and its link to expertise see Texera (1991). On the coexistence of legitimate professionals before 1936 see Freites (1988) and after that Freites (1987). On the role of engineers see Licha (1987) as well as the articles of Gutiérrez mentioned in note 3, and Arvanitis and Bardini (1990, 1992). More examples of scientists–practitioners can be found in the chronicles of Marcel Roche (1988).
6. Arvanitis' (1990) doctoral thesis to be published in Spanish.
7. It has to be noted that these positions are clearly written in two policy documents: the Trompiz Memorandum and the Casperson Commission recommendations, both of which were discussed at the foundation of CONICIT.
8. This is striking in areas such as agriculture. See, for example, the great amount of 'experts' in the Ministry of Agriculture of Venezuela (Balderrama, 1992) and the Ministry of Health.
9. This has been the argument explicitly expressed by Roche against 'applied' science. See Roche's intervention in Aguilera et al. (1983).
10. On these historical aspects there are now numerous published articles. See Díaz et al. (1983) and Vessuri (1983); Freites (1988); Texera (1991); Freites and Texera (1992) and the work compiled in Vessuri (1984, 1987b).
11. See the introduction of Freites and Texera in their compiled book (1992). Also the work of Vessuri (1988) and Texera (1992). An extensive discussion of the role of universities in Venezuela has been published (Di Prisco and Wagner, 1990). This book contains a debate triggered on the theme in *Interciencia* after a fine article by De Venanzi (1987), the rector of the Democratic University in 1958. A review of the prospects and consequences of the debate can be also found in Vessuri (1987b).
12. This continued until the state was forced to create institutions such as the School of Chemistry and Agromony outside the universities (Díaz et al., 1983).
13. All industrial projects were to be submitted to the rules of the Reciprocal Trade Treaty with the US which obliged Venezuela to develop industries that were not in competition with US imports. The Treaty was abandoned in 1970 when industrialization was well under way (see Arenas, 1989).
14. Explanations on the industrialization of Venezuela usually call for an explanation of the technology gap of the country because of economic dependence. Another argument suggests that the gap is due to an insufficient amount of resources dedicated to S&T—an argument much developed and promoted by international institutions like UNESCO (1981). We have challenged these explanations in the first chapter of our book (Pirela, Rengifo, Arvanitis and Mercado, 1991). A conceptual critique of the 'school of dependency' is in Pirela (1990).
15. We know the argument has been challenged. But works on entrepreneurs in Tunisia, China or Taiwan do support the hypothesis that there is a strong cultural component that needs to be present in order to have an entrepreneurial attitude, although there is no concordance on how it emerges (see Sverrisson, 1990; Denieuil, 1992; Berger, 1993). Specifically, on 'industrialization before industrialization' see the important book

of Kriedte et al. (1986). We tend to accept the Baechler hypothesis that the 'bourgeois' entreprenuer emerged in a social space that was not of interest either to the Church or to the power structure—literally a 'meaningless' social area at that moment.

16. Balderrama has called this attitude 'physiocratic dreaming' because the elites have maintained this idea that wealth in Venezuela could be the result of the exploitation of land, when it was obvious that it was oil that nourished the country. One of the main critiques of the parasitic conducts supported by this distributed wealth has been one of the principal advocates for a rational exploitation of the mineral resource and founding father of OPEC, Juan Pablo Pérez Alfonso.
17. This figure is extracted from Bonilla and Michelena (1967). This figure has been supported by a research on innovation in industry by Pirela et al. (1991).
18. Some of these very peculiar entrepreneurs were later on directing not only the more important industrial firms, but they can be found in the list of those who created some scientific institutions. See, for example, the case of the Venezuelan Institute for Industrial Research (INVESTI) (Pirela, 1987). In any case, this participation of the private sector in the growth of science has been much less important than in other Latin American countries, as for instance Mexico. For a comparison see Story (1986).
19. The bibliography on the CONICIT is quite extensive (see Avalos and Rengifo, 1978; Texera, 1983; Rengifo, 1986). The most important critique of CONICIT's role is in the book by Antonorsi-Blanco and Avalos (1980).
20. This is the date of the publication of the Venezuela Report of the Science and Technology Instruments Projects, financed by the Canadian IDRC, The Organization of American States and many international and national institutions. The project aimed at comparing the S&T policies of Venezuela, Colombia, Argentina, Peru, Egypt, Yugoslavia, South Korea and India. The Venezuelan team was coordinated by Ignacio Avalos and R. Rengifo, who was a team member (see Avalos and Rengifo, 1975).
21. CONICIT is directly assigned to the Presidency of the Republic. It was a Ministry for Science and Technology from 1985 until February 1992.
22. This has also been the argument used by Roche and Freites when they examined the lack of influence of CONICIT's priorities on scientists (see Díaz et al., 1983).
23. Figures are quite uncertain, even in the later diagnosis by CONICIT (1973) or the 1983 bulletin 'Ciencia y Tecnología en Cifras'. One of us has attempted a more precise measurement (see Annex 1 of Arvanitis, 1990) which is based on publication figures and various particular studies. We arrived at an estimation of between 600 and 1,200 researchers for 1985. The CONICIT at that moment spoke of 3,000 researchers. The figures we had obtained were a good guess since the Programme for the Promotion of Researchers finally financed little more than 600 researchers when it was initiated in 1991.
24. A similar point of view has been expressed in quite different terms by Vessuri in the debate over the social role of scientists in Venezuela (see Auguler et al., 1993).
25. The whole process has been extensively examined and criticized by Antonorsi-Blanco and Avalos (1980).
26. To examine the details of this process would be beyond the scope of this chapter. Let us only mention that this progressive autonomy of the 'planning function' (and not the institution itself) belongs to the category of phenomena that can be titled 'monsters produced by reason'. Moreover, it is not all of CONICIT that was concerned but a specific function driven by specific cliques of sociologists, economists and engineers.
27. The literature on this topic is now abundant. A good theoretical overview of this new area is given in Dosi et al. (1988) and Dosi et al. (1990). The recent OECD report on technology and the economy is quite a definitive reference (OECD, 1992a).
28. It should be remembered that this was not a unique phenomenon. Chemistry and the chemical industry in the 1930s in Germany and in the US invented a science that was entirely devoted to industry but with very basic and academic interests (see Haber, 1971; Freeman et al., 1982; Aftalion, 1989).

29. This is more a prospective than a retrospective part. May we just remind the attentive reader that our proposal of studying the actors at the micro level, with particular emphasis on their cultural determinants, was undertaken by the need for such a prospective proposal in the early 1980s.
30. This situation where funds exist and no demand emerges was known much before the opening of the economy in Venezuela (see the reports of the July 1986 Conference organized by CONICIT on 'Funds for the Financing of Technological Research'). In other countries, the same phenomenon appears. See the case of Colombia (Lópes, 1987).
31. The word is coined by Freeman (Freeman, 1987) and the economists at Lund (Lundvall, 1992), but now has a much larger scope (Nelson, 1993).
32. 'Firms and Academics: An Impossible Marriage' (Arvanitis et al., 1988) was the title of our first essay on the theme (Pirela, Rengifo, Arvanitis and Mercado, 1991, Chapter 4).
33. The research on firms began in 1987. A history of the project has been reported in Arvanitis and Pirela (1993). Two different surveys were realized in 1988 and 1992. Most results of the 1988 research have been reported in the publications of the research members of the team refered to in this article and the 1992 survey has been presented in an international conference on 'Conducta empresarial y cultura technológica en América Latina: La industria química y petroquímica', Caracas, March 1992.
34. The basic difference between a 'technical task' link with the universities and a 'research link' with them has been extensively reported in Pirela, Arvanitis, Rengifo and Mercado (1992).
35. This research was financed by the Instituto de Ingenieria, a dependent of the Ministry of the Economy and to a less degree by ORSTOM, University of Zulia and Fundacite-Zulia. Rengifo and Pirela along with Gerardo Díaz and Eduardo Ynaty designed the survey (Pirela, Rengifo and Ynaty, 1991).
36. The information comes from a survey of 150 researchers, of whom 100 are located in Caracas and fifty in Maracaibo. The sampling was taken from the fields of science (59 per cent) and technology (41 per cent) from the registry of researchers compiled by the Programme for the Promotion of Researchers, except for Maracaibo where a special registry was compiled.
37. As was the case in Germany (Meyer-Kramer, 1990), but not for instance in Japan (see Freeman, 1988). For an extension of the concept of the system of innovation see the work by Lundvall (1992). A somewhat more descriptive approach is promoted by some researchers (OECD, 1992a, 1992b; Nelson, 1993).
38. This also corresponds to findings of other authors on the science–technology relation, such as the classical work by Freeman (1974) or by Gibbons and Johnston (1974), analysis of specific research projects as done by Maguire and Kench (1984) and the work on the global relation between science and technology by Mowery and Rosenberg (1989).
39. This is why we are not comparing the view of Roche and Freites that the Venezuelan scientific community has been moving from rise to twilight, although we do accept that the dangers the community has been facing are not simple and could convert to a nightmare. Moreover, their data is quite old (1976–1978 survey). That is the reason why they project a 'practically idyllic' image of the scientific community (Roche and Freites, 1992).

## References

**Aftalion, M.** (1989). *Histoire de l'industrie chimique*. Paris: Masson.

**Aguilera, M., V. Rodríguez** and **L. Yero** (1983). *La participación de la comunidad científica frente a las alternativas del desarrollo*. Caracas: AsoVAC.

**Antonorsi-Blanco, M.** and **I. Avalos** (1980). *La planificación ilusoria. Ensayo sobre la experiencia venezolana en política científica y tecnológica*. Caracas: CENDES/Ateneo de Caracas.

**Ardila, M.** (1981). 'Orígen y Evolución Histórica de la Asociación Venezolana para el Avance de la Ciencia'. Tesis Licenciatura. Caracas: UCAB.

**Arenas, N.** (1989). *El Tratado de Reciprocidad Comercial Venezuela—USA*. Caracas: Ed Centro Venezalano Americano.

**Arvanitis, R.** (1990). 'De la recherche au développement. Les politiques et pratiques professionnelles de la recherche appliquée au Vénézuéla'. PhD thesis. Universite de Paris 7.

**Arvanitis, R.** and **T. Bardini** (1990). 'Le rôle de l'ingénieur agronome dans la situation politique de l'argiculture vénézuélienne: 1936–1948'. *Cahiers de Sciences Humaines*, 26 (3), 429–46.

———. (1992). 'El papel del ingeniero agrónomo en el contexto político de la agriculture venezolana', in Y. Freites and Y. Texera (eds.). *Tiempos de cambio. La ciencia en Venezuela 1936–1948*. Caracas: Fondo Editorial Acta Científica Venezolana.

**Arvanitis, R.** and **A. Pirela** (1993). 'Le comportement des entreprises face à la technologie et l'ajustement structurel: L'industrie chimique au Vénézuéla'. Rapport final de recherche pour le Ministère de la Recherche et la Technologie, Paris (Décision d'Aide 91-L-0583), Juin 1993. Paris, Caracas and México: ORSTOM and CENDES.

**Arvanitis, R., A. Pirela, R. Rengifo** and **A. Mercado** (1988). 'Empresarios y Académicos: Un matrimonio imposible?'. Mimeo. Caracas: CENDES.

**Auguler, Rodriguez** and **Yerro** (1993). *La Participacion de LA Comunidad Cientifica en el Desarrollo*. Caracas: ACTA Cientifica.

**Avalos, I** (1984). 'Breve historia de la política tecnológica venezolana', in M. Naim and R. Pivango (eds.). *Venezuela: UNA Ilusion de Armonía*. Caracas: IESA.

———. (1991). 'La Politica Technologica Venezolana: De La Economia Prolégìda a la Economia Abiertu', *Revista ESPACIOS*, 12 (2).

**Avalos, I.** and **R. Rengifo** (1975). *Informe final L Proyeeto Mecanismos Instrumentos de politica cientifia y Technologica*. Caracas: CONICIT.

**Avalos,** T. and **R. Rengifo** (1978). 'Criticas Al 1[er] Plan de C&T'. Mimeo. Caracas: CONICIT.

**Balderrama, R.** (1992). 'Los primeros doce años del Ministerio de Agricultura y Cría', in Y. Freites and Y. Texera (eds.). *Tiempos de cambio. La ciencia en Venezuela de 1936 a 1948*. Caracas: Fondo Editorial Acta Científica Venezolana.

**Berger, B.** (1993). *la cultura empresarial* (The Culture of Entrepreneurship). México: Ediciones Gernika. English translation published by Institute for Contemporary Studies: San Francisco, CA.

**Bonilla,** T. and **S. Michelena** (1967). *Cambio Politico en Venezola*. Caracas: CRÁFICA AMERICANA.

**CONICIT** (1973). 'Diagnóstico de la Actividad de Investigación y Desarrollo Experimental que se realiza en el País'. Mimeo. Caracas: CONICIT/Dept. de Sociología y Estadística.

———. (1986). *Funds for the Financing of Technological Research*. Caracas: CONICIT.

**De Venanzi, F.** (1987). 'Investigación y docencia en la Universidad', *Interciencia*, 12 (5), 221–25.

**Denieuil, P.-N.** (1992). *Les entrepreneurs du développement. L'ethno-industrialisation en Tunisie: la dynamique de Sfax*. Paris: L'Harmattan, Coll.Logiques Sociales.

**Di Prisco, C.A.** and **E. Wagner** (1990). 'Investigación y docencia en las universidades', *Interciencia*, Fondo edit. Acta Cient. Venez.

**Díaz, E., Y. Texera** and **H. Vessuri** (1983). *La ciencia periférica*. Caracas: Monte Avila.

**Dosi, G., C. Freeman, R. Nelson, G. Silverberg** and **L. Soete** (eds.) (1988). *Technical Change and Economic Theory*. London: Pinter Publishers.

**Dosi, G., K. Pavitt** and **L. Soete** (1990). *The Economics of Technical Change and International Trade*. London: Harvester Wheatsheaf.

**Freeman,** C. (1974). *The Economics of Industrial Innovation* ('La teoría económica de la innovación industrial'). Madrid: Alianza Editorial.

———. (1987). *Technology Policy and Economic Performance: Lessons from Japan*. London: Pinter Publishers.

———. (1988). 'Japan: A New National System of Innovation?', in G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds.). *Technical Change and Economic Theory*. London: Pinter Publishers.

**Freeman, C., J. Clark** and **L. Soete** (1982). *Unemployment and Technical Change*. London: Pinter Publishers.

**Freites, Y.** (1984). 'La institucionalización del ethos de la ciencia: el caso del IVIC', in H. Vessuri (ed.). *Ciencia Académica en la Venezuela moderna*. Caracas: Fondo Editorial Acta Científica Venezolana.

———. (1987). 'La Academia de Ciencias Físicas, Matemáticas y Naturales. Una concepción de la ciencia en Venezuela', in H. Vessuri (ed.). *Las instituciones científicas en la historia de la ciencia en Venezuela*. Caracas: Fondo Editorial Acta Científica Venezolana.

———. (1988). 'La ciencia en la época del Gomecismo'. *Quipu*, 4 (2), 213–52.

**Freites, Y.** and **Y. Texera** (1992). *Tiempos de cambio. La ciencia en Venezuela de 1936 a 1948*. Caracas: Fondo Editorial Acta Científica Venezolana.

**Gasparini, O.** (1969). *La investigación en Venezuela: Condiciones de su desarrollo*. Caracas: Publicaciones IVIC.

**Gibbons, M.** and **R. Johnston** (1974). 'The Roles of Science in Technological Innovation'. *Research Policy*, 3 (2), 220–42.

**Gutiérrez, A.T.** (1992). 'La búsqueda de una ilusión. La investigación sobre malaria', in Y. Freites and Y. Texera (eds.). *Tiempos de cambio. La ciencia en Venezuela 1936–1948*. Caracas: Fondo Editorial Acta Científica Venezolana.

**Haber, L.F.** (1971). *The Chemical Industry 1900–1990*. London: Oxford University Press.

**Kriedte, P., H. Medick** and **J. Schlumbohm** (1986). *Industrialización antes de la industrialización* ('Industrialization Before Industrialization, 1977'). Barcelona: Editorial Crítica.

**Licha, I.** (1987). 'El impacto modernizador de la ingeniería sanitaria en Venezuela: el caso del INOS y otras instituciones sanitarias', in H. Vessuri (ed.). *Las instituciones científicas en la historia de la ciencia en Venezuela*. Caracas: Fondo Editorial Acta Científica Venezolana.

**Lópes, A.** (1987). 'La innovación tecnológica en el sistema alimentario colombiano', Seminario de Eestion Technologica. Seminario ALTEC, September, México.

**Lundvall, B.A.** (ed.) (1992). *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning*. London: Pinter Publishers.

**Maguire, C.** and **R. Kench** (1984). 'Sources of Ideas for Applied University Research, and Their Effects on the Application of Findings in Australian Industry'. *Social Studies of Science*, 14 (3), 271–397.

**Meyer-Kramer, F.** (1990). *Science and Technology in the Federal Republic of Germany*. Essex: Longman Publishers.

**Mommer, B.** (1987). *La renta petrolera y su distribución en el desarrollo del capitalismo rentistico venezolana*. Caracas: CENDES/ILDIS.

———. (1989). 'Las medidas económicas del Gobierno y el futuro del país, Entrevista de Nelson Prato Barbosa al Area Económica de CENDES'. *Cuadernos del CENDES*, 9 (10), 55–79.

**Mowery, D.** and **N. Rosenberg** (1989). *Technology and the Pursuit of Economic Growth*. Cambridge: Cambridge University Press.

**Nelson, R.R.** (ed.) (1993). *National Innovation Systems. A Comparative Analysis*. New York: Oxford University Press.

OECD (1992a). *La technologie et l'économie. Les relations déterminantes*. Paris: OECD.

——— (ed.) (1992b). *Special issue on innovation surveys*. STI Revue. Paris: OECD.

**Pérez, C.** (1985). 'Microelectronics, Long Waves and the World Structural Change: New Perspectives for Developing Countries'. *World Development*, 13(3), 441–63.

**Pirela, A.** (1984). 'Crisis de la imitación, imitación de la crisis'. *Tierra Firme*, 2(2), 351–70.

———. (1987). 'El INVESTI y la innovación tecnológica', in H. Vessuri (ed.). *Las instituciones científicas en la historia de la ciencia en Venezuela*. Caracas: Fondo Editorial Acta Científica Venezolana.

———. (1990). *La escuela latinoamericana de pensamiento económico social (Cepal-Dependencia)*. Caracas: CENDES/Vadell Hmnos.

**Pirela, A.** and **R. Rengifo** (1991). 'La conducta académica ante la vinculación Universidad empresa', in ALTEC (ed.). *IV Seminario de Gestión Tecnológica*. Caracas: ALTEC.

**Pirela, A., R. Rengifo** and **R. Arvanitis** (1991). 'Vinculaciones Universidad-Empresa en Venezuela: Fábula de amores platónicos y cicerones'. *Acta Científica Venezolana*, 42, 239–46.

**Pirela, A., R. Rengifo** and **E. Ynaty** (1991). 'Estudio sobre la participación de investigadores del estado Venezolano en el desarrollo industrial del pais', in R. Waast and A. El-Kenz (eds.). *Emergence des communautés scientifiques dans les pays en développement: 2ème atelier du réseau Alfonso*. 24–31 mai. Annaba (Algérie) and Paris: ORSTOM/Centre de Gestion de Annaba.

**Pirela, A., R. Rengifo, R. Arvanitis** and **A. Mercado** (1991). 'Conducta empresarial y cultura tecnológica. Empresas y centros de investigación en Venezuela'. Mimeo. Caracas: CENDES.

**Pirela, A., R. Arvanitis, R. Rengifo** and **A. Mercado** (1992). 'Entrepreneurs et chercheurs face aux technologies industrielles: la production et le transfert de technologie au Venezuela', in H. Drouvot, M. Humbert, J.C. Neffa and J. Revel-Mouroz (eds.). *Innovations technologiques et mutations industrielles: Argentine, Brézil, Mexique, Venezuela*. Paris: Editions IHEAL.

———. (1993). 'Technological Learning and Entrepreneurial Behaviour: A Taxonomy of the Chemical Industry in Venezuela'. *Research Policy*, 22(1), 431–53.

**Rengifo, R.** (1986). 'Ciencia y Política en Venezuela: del espejismo al simulacro'. *Revista Espacios*, 6(6), 17–37.

———. (1990). 'La emergencia de la comunidad científica venezolana', in R. Waast (ed.). *Emergence des communautés scientifiques. Premier atelier du réseau Alfonso*. Paris: ORSTOM.

**Roche, M.** (1987). 'El discreto encanto de la marginalidad. Historia de la Fundación Luis Roche', in H. Vessuri (ed.). *Las instituciones científicas en la historia de la ciencia en Venezuela*. Caracas: Fondo Editorial Acta Científica Venezolana.

———. (1988). *Mi compromiso con la ciencia*. Caracas: Monte Avila.

**Roche, M.** and **Y. Freites** (1992). 'Rise and Twilight of the Venezuelan Scientific Community'. *Scientometrics*, 23(2), 267–89.

**Ruiz Calderón, H.** (1987). 'Cambio y permanencio en los modelos de institucionalización de la actividad científica en Venezuela: el caso de la físico en el IVNIC-IVIC', in H. Vessuri (ed.). *Las instituciones científicas en la historia de la ciencia en Venezuela*. Caracas: Fondo Editorial Acta Científica Venezolana.

———. (1992a). 'Ciencia, tecnología y modernización en Venezuela', in *La ciencia en Venezuela: pasado, presente y futuro*. Caracas: Lagoven S.A.

———. (1992b). 'La ciencia y la tecnología y el programa de Febrero', in Y. Freites and Y. Texera (eds.). *Tiempos de cambio. La ciencia en Venezuela 1936–1948*. Caracas: Fondo Editorial Acta Científica Venezolana.

**Silva Michelena, A.** and **H. Sonntag** (1970). *Universidad, dependencia y revolución*. DF México: Siglo XXI editores.

**Story, D.** (1986). *Industria, estado y política en México. Los empresarios y el poder*. DF México: Grijalbo/ConaCult.

**Sverrisson, A.** (1990). *Entrepreneurship and Industrialisation. A Case Study of Carpenters in Mutare, Zimbabwe*. Lund, Sweden: Research Policy Institute, University of Lund.

**Texera, Y.** (1983). 'Cientificismo y política: el caso del CONICIT venezolano'. *Acta Científica Venezolana*, 34, 275–85.

———. (1991). *La Exploración botánica en Venezuela (1754–1950)*. Caracas: Fondo Editorial Acta Científica Venezolana.

———. (1992). 'La Facultad de Ciencias de la Universidad Central de Venezuela', in C. Lagoven (ed.). *La ciencia en Venezuela*. Caracas: Central University y Venezuela.

UNESCO (1981). *Introduction à l'analyse politique en science et technologie*. Paris: UNESCO.
Vessuri, H. (ed.). (1984). *Ciencia académica en la Venezuela moderna*. Caracas: Fondo Editorial Acta Científica Venezolana.
———. (1987a). 'The Social Study of Science in Latin America'. *Social Studies of Science*, 17(3), 519–54.
———. (1987b). *Las instituciones científicas en la historia de la ciencia en Venezuela*. Caracas: Fondo Editorial Acta Científica Venezolana.
———. (1988). 'El proceso de profesionalización de la ciencia venezolana: la Facultad de Ciencias de la Universidad Central de Venezuela'. *Quipu*, 4(2), 253–84.
———. (1992). 'Ciencia, tecnología y modernización en Venezuela, segundo periodo 1959–1990', in *La ciencia en Venezuela: pasado, presente y futuro*. Caracas: Lagoven S.A.

# Contributors

**Rigas Arvanitis** is an economist and sociologist of science. He has been working on the relations between the scientific community and the productive sector in Venezuela. He has also carried out a research project on technological development and learning in the chemical industry in Venezuela and Latin America in collaboration with his colleagues from the Centre for Research on Development (CENDES) at the Central University of Venezuela. He now works at the Metropolitan University (UNAM) of Mexico along with the Master's programme on Economics of Technical Change on a similar research programme in Mexico. One of his main interests has been the development of appropriate indicators for the evaluation of the research effort of scientists in the developing world. He has published in numerous journals including *Scientometrics, Research Policy* and *Social Studies of Science.*
**Antonio Botelho** is a PhD in political science from MIT. He holds graduate degrees from the Federal University of Rio de Janeiro, Cornell University, and the Conservatoire National des Arts et Métiers, Paris. He is currently a Visiting Scholar in the Department of History and Sociology of Science, University of Pennsylvania. He has been a consultant to a number of international and governmental organizations. He has done historical and political research on high-tech development in developed and developing nations, and on various aspects of S&T policy for development. Recent articles on the subject have appeared in *Historia Scientarum, Social Studies of Science* and other journals.
**Yvon Chatelin** has been working in tropical Africa as a soil scientist for almost twenty years since 1958. The problems he encountered in his field as well as multi-disciplinary teamwork led him to get involved in methodological enquiries. He has carried out historical, epistemological and linguistic studies on natural sciences. He has been active in the sociology of sciences during the last ten years, more particularly in bibliometrics. He is the author of several books (in soil sciences, history, epistemology and sociology of sciences) including *Stratégies scientifiques et développement—sols et agriculture des régions chaudes* in collaboration with Rigas Arvanitis (Paris: ORSTOM, 1988) and *Le voyage de William Bartram* (Paris: Karthala—ORSTOM, 1991).
**Charles H. Davis** is Principal Programme Officer with the Programme on Innovation Systems Management (PRISM) at the International Development Research Centre (IDRC). IDRC supports research in the social, natural and applied sciences on problems of development. Dr. Davis was previously an S&T policy researcher with the Science Council of Canada

and the Conseil de la Science et de la Technologie du Québec. Dr. Davis completed his doctoral work in science policy at the Université de Montréal. His present research and programme interests include management of technology and innovation in developing countries, innovation support infrastructure, environmentally sustainable industrial innovation and the implications of trade liberalization for S&T policies. Recent articles have appeared in *Scientometrics* and *International Journal of Technology Management*.

**Thomas Owen Eisemon** is a senior education specialist in the Education and Social Policy Department at the World Bank. He is also Professor and Director of the Centre for Cognitive and Ethnographic Studies at McGill University. Dr. Eisemon has published extensively on science and higher education in African and Asian countries. He is the author of several books including *The Science Profession in the Third World: Studies from India and Kenya* (New York: Praeger, 1982). Recent articles on the subject have appeared in *Minerva, International Studies in Sociology and Social Anthropology, Higher Education* and other scholarly journals.

**Jacques Gaillard** is an engineer from the Ecole Nationale d'Agriculture d'Angers and a sociologist of science. He received his doctorate degree in science, technology and society from the Conservatoire National des Arts et Métiers, Paris. He has been scientific secretary of the International Foundation for Science (IFS), Stockholm, during 1975–1985. Part of his work included in the present volume has been prepared while he was Visiting Fellow at the George Washington University, Washington, DC, during 1991–1994. His present research interests also include the comparative analysis of research policies for development, international scientific migrations and the evaluation of research. He is the collaborating editor for *Science, Technology & Society* for Africa. His recent books include *Scientists in the Third World* (Kentucky: The University Press of Kentucky, 1989) and *Science Indicators for Developing Countries*, co-edited with R. Arvanitis (Paris: ORSTOM, 1992).

**Anne Sophie Keller** is a PhD candidate in socio-anthropology. She participated in the evaluation of the STD II Programmes of the European Community.

**Ali El Kenz** is Professor of Sociology at the University of Nantes, France and Invited Professor at the Université de Tunis. He is co-founder of the Arab Association of Sociology, and Director of Programmes at the Council for the Development of Social Science Research in Africa (CODESRIA). Philosopher by training, he first worked in sociology of work and then in sociology of knowledge. He was the director of a research team at CREAD (Algiers) that carried out field surveys in these two areas. He has published numerous research articles and several books including *L'économie de l'Algérie* (Paris: Maspéro Collection Textes à l'aupul, 1980) and *Le complexe sidérurgique d'El Hadjar* (Paris: CNRS, 1987).

V.P. **Kharbanda** is a postgraduate in botany from the University of Delhi and a Master's degree holder in the Chinese language from Jawaharlal Nehru University, New Delhi. He joined CSIR, New Delhi, in 1974 and since then he is engaged in comparative studies on science, technology and development policy issues in India and China. He has published more than thirty research papers and three books. Presently, he is working as a senior scientist in NISTADS, CSIR, New Delhi, and is engaged in a joint research project on S&T strategies in India and China in collaboration with the Central South University of Technology, Changsha, Hunan Province, China. He is the co-author of *Science, Technology and Economic Development in China* (New Delhi: Navrang Publishers, 1987).

V.V. **Krishna** is a senior scientist at NISTADS, CSIR, New Delhi. He is heading research programmes on sociology of science and technology, and contemporary history of science at the institute. He is an editor of *Science, Technology & Society*, a journal published by Sage, New Delhi. He holds a PhD in sociology of science from the University of Wollongong, Australia and has been working in the social studies of the S&T field for the last seventeen years. His recent papers have been published in *Knowledge and Policy, Journal of the Indian Sociological Association* and in the monograph series of the *Boston Studies in the Philosophy of Science*. He has also recently published a volume on *S.S. Bhatnagar on Science, Technology and Development: 1938–54* (New Delhi: Wiley Eastern Ltd, 1993).

**Jean-Baptiste Meyer** is a graduate of the Institute of Development Studies, Geneva. He holds a Master of Arts in international relations studies from Boston University and a PhD in sociology of science from the National School of Mines, Paris. He is a researcher in the Science, Technology and Development (STD) Programme at ORSTOM. He is presently coordinating an international study entitled 'The Brain Drain Revisited Through the Case of Colombia', which reconsiders the current theories in migration of scientists from the particular case of the Colombian scientific diaspora.

**Arnoldo Pirela** is a senior researcher at the Centro de Estudios del Desarrollo (CENDES), Central University of Venezuela (UCV). He is also coordinator of the project 'Entrepreneurial Behaviour and Technological Culture in Latin America', technical director of the Permanent Commission for Science and Technology of the Venezuelan National Parliament, and consultant on technology management and competitive strategies. He holds a degree in business administration from UCV in Caracas, a diploma in economics, an MSc degree in organization and structure of science and technology from the United Kingdom and a PhD in development studies from CENDES, Caracas.

**Rafael Rengifo** is a researcher on social studies of science and technology at the Centro de Estudios del Desarrollo (CENDES), Central University of Venezuela (UCV). He is also involved in the project 'Entrepreneurial Behaviour and Technological Culture in Latin America' and collaborates in the project on the 'Emergence of Scientific Communities in Developing Countries' with ORSTOM. He is also a researcher and a consultant on the subject of organizational learning and culture, new strategies of knowledge, and studies in sociology and anthropology at the University of Chile, Santiago, and UCV, Caracas.

**Simon Schwartzman** was Professor of Political Science and Scientific Director of the Research Group on Higher Education at the University of Sao Paulo, and senior researcher at the Fundaçao Getulio Vargas, Brazil. Currently, he is President, IBGE at Rio de Janeiro. He holds a PhD degree in political science from the University of California, Berkeley. He has been the rapporteur of the Brazilian Presidential Commission on Higher Education in 1985 and coordinator of the Science and Technology Policy Study organized by the Getulio Vargas Foundation for Brazil's Ministry of Science and Technology in 1993. He is the author of numerous articles and has published several books including *A Space for Science: The Development of the Scientific Community in Brazil* (The Pennsylvania University Press, 1991).

**Shen Aiqun** is a senior engineer and Head, Department of Research Management of the Institute of Policy Management, Chinese Academy of Sciences, Beijing. She has been working in the area of S&T studies and quantitative aspects of S&T during the last decade. She is currently working on a joint collaborative project on China and India in S&T with NISTADS, New Delhi.

**Hebe Vessuri** is Head, Department of Science Studies and directs a graduate programme in the social study of science at the Instituto Venezolano de Investigaciones Cientificas (IVIC), Caracas. She also holds the UNESCO Chair on the 'Contribution of Higher Education to R&D in Latin America'. Her field of specialization is the sociology and social history of twentieth century Latin American science, with special emphasis on the interface between science and higher education. She has published recent articles on these subjects in *Minerva, Social Studies of Science* and other scholarly journals. She has edited *La ciencia periférica. Ciencia y sociedad en Venezuela* (Caracas: Monte Avila Editores, 1984); *Ciencia académica en la Venezuela moderna* ((Caracas: CENDES, 1984); *Las instituciones cientificas en la historia de la ciencia en Venezuela* (Caracas: Fondo Editorial Acta Cientifica Venezolana, 1987); *La evaluacion académica. Enfoquea y experiencias, 2 vols*. (Paris: CRE-UNESCO, 1993) and *Cuando la academia va al mercadeo* (Caracas: Fondo Editorial FINTEC, 1995). She has just finished a study on the origins of agricultural science in Venezuela, and is currently working on the development and adaptations of scientific institutions in Latin America. She is the collaborating editor for *Science, Technology & Society* for Latin America.

**Roland Waast** is an engineer from the Ecole Polytechnique, Paris. He also holds a graduate degree in sociology from the Université Paris-Sorbonne.

He is at present coordinating the Science, Technology and Development (STD) Programme at ORSTOM. He is also an editor of *Science, Technology & Society*. During extended stays, first in Madagascar and then in Algeria, he carried out work in rural sociology and in the economy of health. He has co-edited, among others, *Changements sociaux dans l'Ouest Malgache* (Paris: ORSTOM, 1980) and edited *La politique du médicament en Algérie* (Algiers: INSP, 1982). He created a department dealing with development strategies at ORSTOM and is the founder of ALFONSO, an international research network devoted to science, technology and society in the developing world. His present work includes science beyond the metropolis and the emergence of scientific communities in developing countries with particular attention to Arab countries.

**Yang Anxian** is Senior Engineer and Acting Director at the Bureau of Science and Technology Policy, Chinese Academy of Sciences, Beijing. She has been working in the area of S&T policy and social studies of science in China for more than a decade. She has represented China in many official delegations on S&T commissions. She has published papers and reports on Chinese S&T, both in Chinese and international journals.

**A.B. Zahlan** is a science policy consultant presently. He was Professor of Physics for twenty years at the American University of Beirut during 1956 and 1976. He was a founding member and first director of the Royal Scientific Society, Jordan, during 1969 and 1970, and of Arab Projects and Development, Lebanon, during 1973 and 1976. During the past twenty-five years he has undertaken research and consultancy in science policy, more specifically in agriculture policies and systems, international relations in S&T, manpower planning, educational policies, brain drain research in the Arab region, and institution building and efficiency. He has published over 100 papers and twenty-two books. His most recent book is on *Acquiring Technological Capacity: A Study of Arab Consulting and Contracting Firms* (London: Macmillan, 1991).

# Index

In today's world of rapid technological changes, science and technology play a key role in the development of a nation, in improving standards of living and in advancing industrial growth. While the development of a country's S&T potential is enmeshed with various socio-economic and political forces, there is no denying the central role of S&T communities in the overall development process. It is within this context that this important volume explores the constitution and growth of scientific communities and the current state of scientific potential in a wide range of developing countries.

The twelve case studies—six from Africa and three each from Asia and Latin America—which constitute the core of this volume throw ample light on a variety of fundamental questions of direct relevance to developing nations. These include the colonial and post-colonial experiences of the countries studied; the role played by key actors like the state and scientific elites; the influence of differing political systems on the growth of S&T; and the reasons why, despite roughly comparable outlays on developing S&T, the results are skewed and vary dramatically across countries.

A significant feature of this volume is its eclectic approach combining a wide range of perspectives—sociology, history, economics and political science—under the broad rubric of science, technology and society studies. Even though the focus and perspective of each case study vary in many respects, there is an underlying recognition of certain common sociological and historical processes which have shaped the growth of science and scientific communities in the developing world.

Providing a truly comparative perspective on a theme of central importance to developing countries, this volume will attract a wide readership among scholars and professionals in the fields of sociology, economics, history, science and technology studies, science communication and education, development studies, policy studies and social studies of science.

**Jacques Gaillard** is currently Senior Scientist in the Science, Technology and Development Group, ORSTOM, Paris. A trained agricultural engineer with a doctorate in Science, Technology and Society, he was previously Scientific Secretary of the International Science Foundation for Science (IFS), Stockholm, and Visiting Fellow at the George Washington University, Washington, DC. Dr. Gaillard has previously published *Scientists in the Third World* and *Science Indicators for Developing Countries* (co-editor).

**V. V. Krishna** is a Senior Scientist and Head, Sociology of Science Group, NISTADS, New Delhi. With a PhD in the Sociology of Science from the University of Wollongong, Australia, he has been active in the fields of sociology of science, S&T policy studies and the contemporary history of science. Dr. Krishna's recent publications include *S.S. Bhatnagar on Science, Technology and Development—1939–54* and he is currently co-editing a Sociology of the Sciences Yearbook for 1996–1997.

**Roland Waast** is an engineer from the Ecole Polytechnic and holds a graduate degree in sociology. Presently, he is a Research Director at ORSTOM, Paris, and coordinates the Science, Technology and Development Programme. Roland Waast has worked extensively in developing countries such as Madagascar and Algeria. His publications include a series on *Changements Sociaux dans l'Ouest Malgache* (co-editor) and *La politique du médicament en Algérie*.

THE CONTRIBUTORS

Rigas Arvanitis ♦ Antonio Botelho ♦ Yvon Chatelin ♦ Charles H. Davis ♦ Thomas Owen Eisemon ♦ Jacques Gaillard ♦ Anne Sophie Keller ♦ Ali El Kenz ♦ V.P. Kharbanda ♦ V.V. Krishna ♦ Jean-Baptiste Meyer ♦ Arnoldo Pirela ♦ Rafael Rengifo ♦ Simon Schwartzman ♦ Shen Aiqun ♦ Hebe Vessuri ♦ Roland Waast ♦ Yang Anxian ♦ A.B. Zahlan

**Jacket Design by Bharati Mirchandani**