Inventing a better future

ISBN 90-6984-402-8

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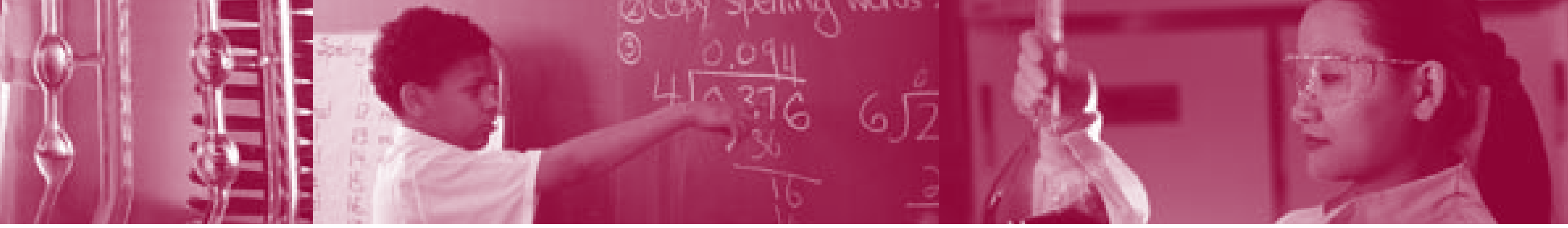


Foreword

The Board of the InterAcademy Council (IAC), at its first meeting in January 2001, decided that its highest priority issue would be the building of greatly increased capacity in science and technology throughout all regions of the world. The underlying premise is that all nations and societies will continue to face many challenges that require the application of up-to-date scientific knowledge and technology for their resolution. Although aware that many other organizations are also deeply concerned with this issue, the IAC Board considered science and technology capacity building to be of such an overarching global importance that it needed to bring the IAC's unique perspectives to bear on the task.

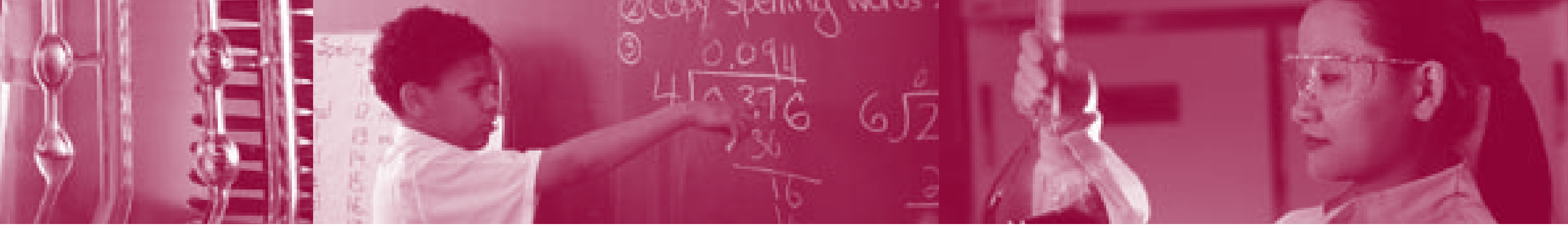
The IAC Board invited the member academies of the 90-nation InterAcademy Panel on International Issues (IAP) to nominate candidates for performing a study on capacity building; and in fall 2001 the IAC Board appointed a Study Panel on Promoting Worldwide Science and Technology Capacities for the 21st Century. Composed of co-chairs Ismail Serageldin of Egypt and Jacob Palis of Brazil plus 10 other distinguished members, the Panel's personal experience in scientific capacity building spans all regions of the world and many scientific disciplines. Its charge was to develop a global strategy for promoting capacities in science and technology as a report from the InterAcademy Council.

The document that follows is the result. First written in draft form, the final report incorporates the Panel's response to an extensive external review process that involved 27 experts plus two distinguished scientists who served as review monitors. We thank all of the Panel members, reviewers, and monitors who contributed to this important effort. Special appreciation is due to the Panel's co-chairs, who put much time and devotion into ensuring that the final product would make a difference. The InterAcademy Council also gratefully acknowledges the leadership exhibited by the Alfred P. Sloan Foundation of New York, which provided the financial support for this study and its dissemination.

The IAC Board is committed to help guide the follow-up efforts that will be required to implement this report's many recommendations. Thus, the publication of this report represents only the first step by the InterAcademy Council in the critical effort to strengthen capacities in science and technology throughout the world.

Bruce ALBERTS
President, U.S. National Academy of Sciences
Co-Chair, InterAcademy Council

Goverdhan MEHTA
Former President, Indian National Science Academy
Co-Chair, InterAcademy Council



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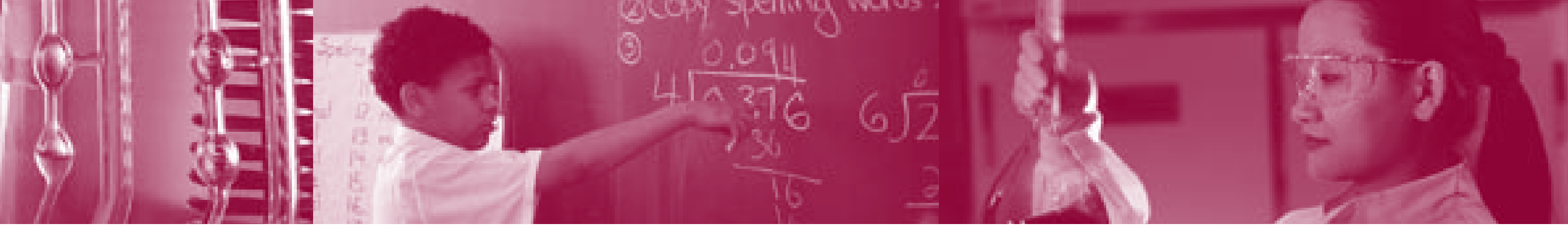

Study panel

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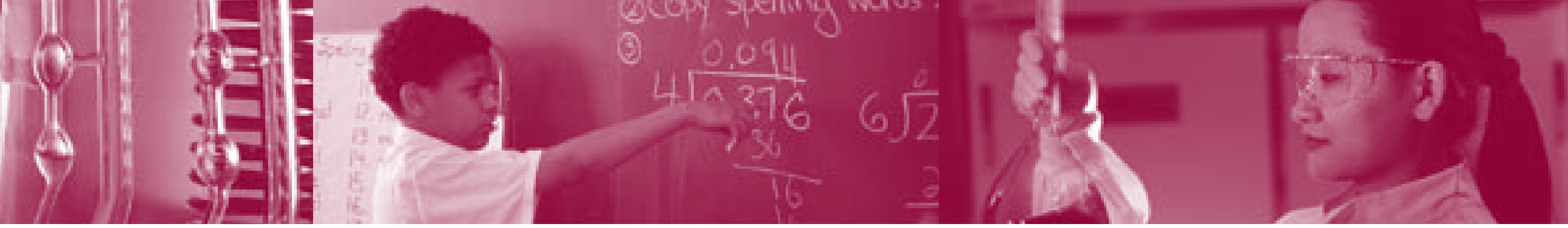


Preface

Intent of this report

In a world moving rapidly toward the knowledge-based economies of the 21st century, capacity building in science and technology (S&T) is necessary everywhere. But the need is greatest for the developing nations. This report is a call for a global movement to address this need, which has been insufficiently addressed when not neglected altogether.

This report is a relatively short document addressing the public in general, as well as decisionmakers – representing government, academia, the private sector, the media, and the civil society – in particular. It is a brief to mobilize concern among all these parties and to trigger actions, and it recommends some ways in which *interactions* between them could be usefully pursued.

The Study Panel states at the outset that this report is not a review of the literature on capacity building, national systems of innovation, or the role of science and technology in development. Nor, given the enormous differences between countries, does the report try to provide highly specific recipes. Differentiated paths to development have been followed by different societies, and there is as much diversity among the successes – exemplified by the report's numerous text boxes – as there is among the failures. The detailed designs of national and institutional strategies should be undertaken by the actors concerned, consistent with their own problems and potentialities; meanwhile, this report can serve as a general guide – a source of inspiration, direction, and ideas.

Although the report's subject has been previously addressed elsewhere, the reader will find that many new ideas and paths of action – aimed at building up S&T capacity around the world – are described here. The growing sense of cooperation among scientific and technological communities of different countries and regions is especially important; it makes these ideas and paths much more practical now than ever before.

Study panel process

The InterAcademy Council (IAC) appointed the Study Panel on Promoting Worldwide Science and Technology Capacities for the 21st Century in November 2001. The charge to the Study Panel was to develop a global strategy for addressing this goal in the form of a report for publication by the IAC. As a contribution to the effort, the Chinese Academy of Sciences sponsored a regional workshop, Science and Technology Human-Resource Management in Asian Developing Countries, in Beijing in April 2002.

During 2002-2003, the Study Panel met five times and engaged in often-spirited discussions and intense deliberations. From these meetings and numerous electronic exchanges of ideas, the Study Panel reached consensus on a set of conclusions and recommendations for enhancing worldwide capacities in science and technology. A draft report of the Study Panel was completed in August 2003 and then revised after an extensive external-review process conducted in September 2003, as required by the rules of procedure of the InterAcademy Council.

Report themes

Global transformations. The Study Panel observes that human societies have benefited enormously from advances in science and technology during the last century: people can live longer, healthier, and more productive lives than ever before. Today, in a new century, we are witnessing greater-than-ever acceleration in the rates of development and dissemination of new knowledge in practically all fields. Whether or not one chooses to describe this phenomenon as a move toward 'knowledge-based societies,' it is nevertheless clear that future economic and social well-being will derive at least as directly from the mastery and creative application of knowledge as they will from the possession and exploitation of tangible materials. This profound transformation

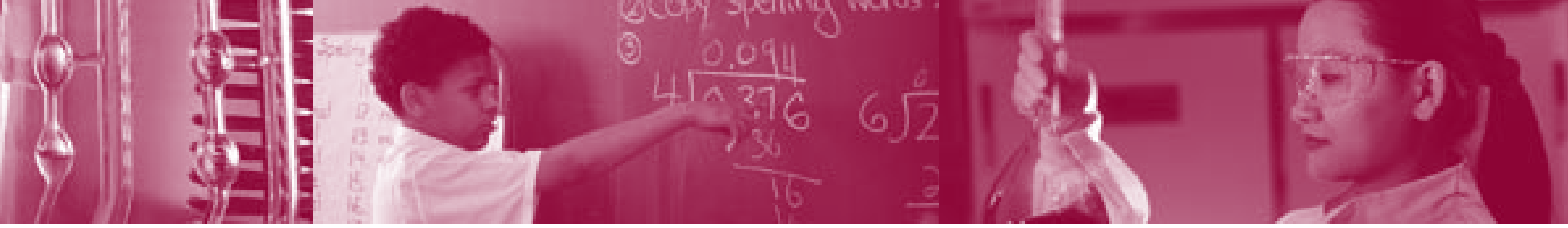
is obviously affecting different parts of the world in very different ways. The industrialized nations have, for all intents and purposes, largely dominated contemporary economic activities and processes, enjoying a preponderance of scientists, laboratories, and investments in research and development (R&D). Consequently, they command an overwhelming share of the patents granted for innovations in an increasingly well-policed international system of intellectual property rights.

Overarching problem. There is always room for improvement in the practice of science and technology and for enhancing research capacity in the high-income industrial world. But the members of this Study Panel believe that the overarching problem is in the low-income developing world: the vast majority of people in most societies are falling farther and farther behind in their ability to master the new knowledge and benefit from its fruits in their everyday lives. The inability of most of the developing world to keep pace with the rapid changes occurring in the various fields of S&T indicates that current models of technology transfer and international assistance are not working as well as many would have hoped. The Study Panel is thus convinced that all nations, particularly the developing ones, require an increased level of S&T capacity to enhance their ability to adopt new technologies – as in those related to the new life sciences – and adapt them to local needs. Enhancing S&T capacity in the developing nations is truly a necessity and not a luxury. There is an urgent need to revisit current practices and propose a comprehensive overhaul of the approach to capacity building for science and technology. That is what the Study Panel has attempted to do in this report.

Emerging consensus. The Study Panel believes that an emerging global consensus on developmental issues, embodied in the United Nations Millennium Development Goals, not only creates a propitious climate for governments (in the industrialized and developing nations alike) to receive new ideas about old and persistent problems but reveals a willingness to see these problems afresh in a pragmatic and strategic light. Awareness of the growing gap – made obvious by the enormous increases in communications capability and connectivity – has created a greater receptiveness to entertaining new recommendations and revisiting past policies in the developing nations, where action on the ground has not kept pace with public rhetoric.

Terms of reference. The Study Panel defines the S&T capacity of a country as the personnel, infrastructure, investment, and institutional and regulatory framework available to generate activities and acquire scientific knowledge and technological capabilities for addressing with competence and creativity local, national, and international needs. In this report, nations are categorized as S&T-advanced, S&T-proficient, S&T-developing and S&T-lagging. It should be clear that such country groupings – whether industrialized vs. developing, or S&T-advanced vs. S&T-proficient vs. S&T-developing vs. S&T-lagging – are approximations. Many countries have geographic and demographic variability in terms of economic and technological development. Developing nations may be advanced in some aspects of science or technology, such as agriculture, but lagging in others, such as information and communications technology. Nevertheless, the countries concerned will recognize themselves and should be able to select from the report the recommendations that are most appropriate to their specific needs.

Some caveats. The Study Panel notes that the recommendations advanced in this report should be considered in the light of important caveats. No set of policy recommendations is likely to be effective in the absence of political stability, the commitment of national political leaders, appropriate national laws and administration, good governance, and the requisite intellectual freedom for the pursuit of knowledge. Equally important is the empowerment of various actors whose interplay is necessary for research and development that addresses societal needs. That being said, however, members of the Study Panel believe that they have adequately surveyed the multi-faceted situation and made recommendations for the various aspects that needed to be addressed.



Challenges for the least-developed countries. Clearly, the recommendations advanced here are more generally suitable for industrialized nations and for those developing nations that have already achieved some sizeable measure of advancement in their national educational, training, and research systems. For the poorest and smallest countries, some of the report recommendations may not be feasible. Thus the Study Panel emphasizes work on a *regional* basis for such nations (i.e., in collaboration with neighboring countries), so that a critical mass of scientific capability can be achieved. These least-developed countries merit special attention in this report in terms of 'South-South' and 'North-South' cooperation and of required commitments for assistance from the S&T-advanced and S&T-proficient countries.

Structure of the report. For clarity, the Study Panel grouped its recommendations into five clusters that deal respectively with policy, human resources, institutions, the public/private interface, and finance. These are described in detail in chapters 2-6, while chapter 1 establishes the setting and chapter 7 offers the outlines of an approach to implementation. A description of the urgent actions required of each of the major institutional actors is presented in annex B.

Call to action. The Study Panel sees all these recommendations as mutually reinforcing, with the whole greater than the sum of the parts. Implementation of only a portion of the package is thus likely to be disappointing, as the historical record shows. An absence of comprehensiveness in the past, as well as the fragmentation of actions (as in their interruption from time to time, or even their termination, because of economic difficulties or a change in government), have deprived all but a few of the developing nations of an effective S&T capacity leading to significant success in national development.

Jacob PALIS
Study Panel Co-chair

Ismail SERAGELDIN
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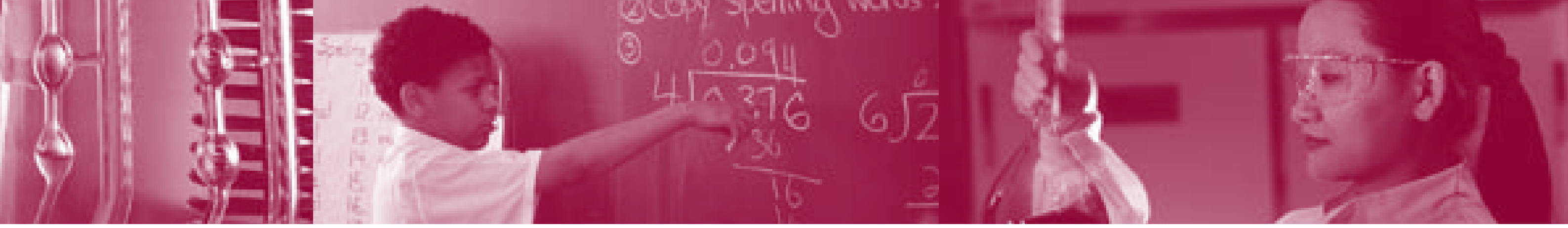

Report review

This report was externally reviewed in draft form by 18 internationally renowned experts chosen for their diverse perspectives, technical knowledge, and geographical representation, in accordance with procedures approved by the IAC Board. The purpose of this independent review was to provide candid and critical comments that would help the IAC to produce a sound report that met IAC standards for objectivity, evidence, and responsiveness to the study charge. In addition, nine reviews were received from members of the IAC Board. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. The IAC wishes to thank the following reviewers of this report:

Berhanu ABEGAZ, Professor of Chemistry, University of Botswana, Gaborone, Botswana

Alice ABREU, Director, Office of Science and Technology, Organization of American States, Washington, DC, USA

James ADAMS, Vice President, The World Bank, Washington, DC, USA

John H. BARTON, Professor of Law, Stanford University, Stanford, California, USA

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Maureen O'NEIL, President, International Development Research Centre, Ottawa, Canada

Nikolai PLATE, Vice President for International Affairs, Russian Academy of Sciences, Moscow, Russia

Ranjan RAMASAMY, Chairman, National Science Foundation, Colombo, Sri Lanka

Tony RIDLEY, Emeritus Professor of Engineering, Imperial College, London, UK

José SARUKHAN, Professor of Ecology, National Autonomous University of Mexico, Mexico City, Mexico

Vincent P.K. TITANJI, Deputy Vice Chancellor, University of Buea, Cameroon

ZHOU Guangzhao, President, China Association for Science and Technology, Beijing, China

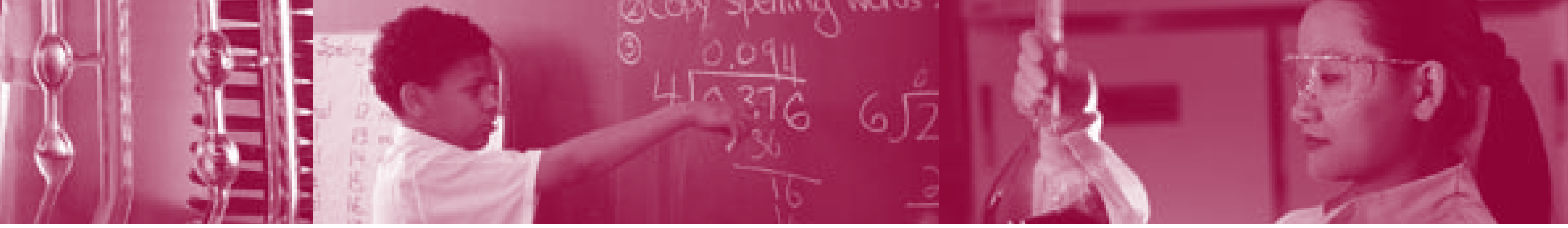
Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions and recommendations, nor did they see the final draft of the report before its release.

The review of this report was monitored by:

Hubert MARKL, Professor of Biology, University of Konstanz, Germany; former President, Deutsche Forschungsgemeinschaft (DFG); former President, Berlin-Brandenburg Academy of Sciences; and former President, Max Planck Society for the Advancement of Science.

M.G.K. MENON, Chairman, Board of Governors of the Indian Institute of Technology, Delhi, India; former Minister of State for Science & Technology, Government of India; former Minister of State for Education, Government of India; former President, Indian National Science Academy; former President, International Council for Science (ICSU).

Appointed by the IAC Co-Chairs, these review monitors were responsible for ascertaining that the independent examination of this report was carried out in accordance with IAC procedures and that all review comments were carefully considered. However, responsibility for the final content of this report rests entirely with the authoring Study Panel and the InterAcademy Council.



Executive summary

Chapter 1: The urgency to promote world-wide science and technology capacity

The world is changing at a rapid pace, driven by science and technology. The accumulation of scientific knowledge and its technological applications are accelerating at a dizzying clip, enabled in large part by ever more powerful computers and lightning-fast communications. Yet the global reality is that many innovations fail to accrue to those who need them most; and benefits are not at all shared equitably around the planet. The international community has given inadequate attention to the needs of capacity building in science and technology (S&T) as the engine that drives knowledge-based development. It is precisely this issue – the need to correct that critical omission – that we address here: the available personnel, infrastructure, investment, institutions, and regulatory framework to conduct scientific research and technological development.

Business-as-usual will leave an ever-growing gap between 'have' and 'have-not' nations. A vicious cycle is at work whereby the developing nations (especially the S&T-lagging countries) fall farther and farther behind the industrialized nations that have the resources – in financial as well as human-development terms – to apply scientific advances and new technologies ever more intensively and creatively. The current disparity is likely to grow even wider as the industrialized nations continue to master the tools of science and invention, vastly outspend the developing nations in research and development (R&D), and even capture some of the developing nations' most precious human resources for their own use.

Local S&T capacity is essential for using and contributing to the world's valuable store of knowledge. Leaving the scientific and technological breakthroughs to the highly industrialized nations and expecting the rest of the world to benefit from the results is an illusory and unproductive policy. The tools involved in such breakthroughs are often very sophisticated and their use requires a great deal of knowledge at the local level, as well as an ability to adapt and extend them to meet local needs.

Universities have an essential role to play in building S&T capacities. The university in developing nations has a special function as a locus for the modernizing forces of society, for the promotion of the 'values of science,' and for mediating between the political and industrial spheres of a nation's life. The university's research facilities in particular must orchestrate the brainpower of the faculty, take responsibility for training new generations of talent, and participate in the transformation of the nation's S&T base. Regrettably, the current structures of higher-education systems in many countries are inadequate to meet the challenges of the 21^{st} century. Wide-ranging reforms are needed.

The culture and values of science are critical for building a global community. Science is not only itself a culture of global dimensions, it induces a cultural current that strongly and positively affects societies in which it flourishes – including those that at first were wracked by poverty and hunger, riven by civil strife, and embedded in fiscal crisis. Science brings imagination and vision to bear across the board – on theoretical speculations as well as on practical problems and critical decisions – allowing people to analyze present (and future) situations, make sounder choices, and invest their resources more wisely. The culture of science and the open, honest values that it engenders are enormously important above and beyond the material benefits that they help produce for human welfare.

Investments in science and technology are increasingly important for economic growth. While it is not possible to demonstrate a direct causation between the rates of investment in research and development and outcomes in terms of increased national Gross Domestic Product (GDP), it is true that a growing level of investment in research and development is generally correlated with improved GDP-growth outcomes. When national research and development activities are taken as a whole, it is seen that the high-income industrialized nations – Australia, Canada, Japan, South Korea, the United States, and northern and western Europe – all spend between 1.5 percent and 3.8 percent of their GDP on research and development. National governments in developing nations should increase their spending considerably, certainly above 1 percent of GDP and preferably closer to 1.5 percent, if there is to be any hope of not falling farther behind the industrialized states.

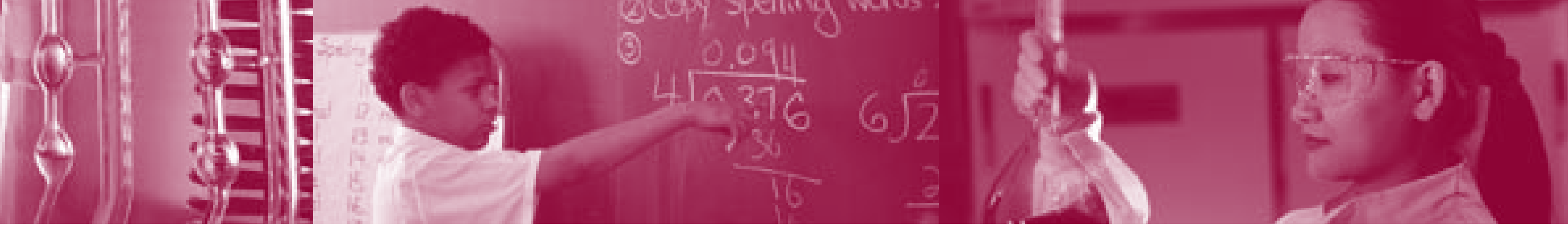
Building capacity in agriculture, engineering, health, and the social sciences is essential for national development. In the developing world especially, the need for problem-solvers working together in interdisciplinary and systems-level fashion is critical. In all the needed areas of a society's interaction with science and technology, agriculture, engineering and medicine, should loom large. And the development of capacity in social science should be regarded as no less important. Well-trained and insightful economists, sociologists, anthropologists, political scientists, public administrators, and other social-science professionals are especially important for providing policy analyses, developing the S&T culture, building institutions, and maintaining the public-private interface for S&T promotion.

Our recommendations represent universal needs for inventing a better future. Stronger S&T capacity in the developing nations is not a luxury but an absolute necessity if these nations are to participate as full partners in the world's fast-forming, knowledge-based economy. Because S&T capacity building is likely to be demanding and far-reaching, and necessarily tailored to each country's particular situation, it will require the involvement of all pertinent actors in its implementation. There is much that national governments can do and much that other groups of social actors – such as local governments, nongovernmental organizations, the private sector, international and regional organizations, the S&T communities, philanthropies, and the media – can do to change the course of events so that the benefits of science and technology flow more equitably to all members of the human family.

Chapter 2: Science, technology, and society

National S&T strategies identify priorities for addressing critical needs. Each nation requires a coherent national framework for actions that directly affect the promotion of science and technology. Such a national S&T strategy should be developed by the government in consultation with scientific, engineering, and medical academies of the country. The strategy should benefit from the experiences of other countries, and it should spell out the government's commitments to funding, standards of excellence, openness to innovation, dissemination of knowledge, regional consortia and networks, private-public interactions, and entry into partnerships with others – locally, regionally, and globally.

- Every nation should develop an S&T strategy that specifies the national priorities for research and development and spells out national funding commitments.
- National governments should develop national strategies for science and technology in full consultation with the country's science, engineering, and medical academies, its professional societies, and the industrial sector.
- The national strategies should include support for basic science and recognize the need for high-level training to develop, as much as possible, national competence in selected frontier areas of science and technology that are most suitable for sustainable economic development and social well-being.
- National funding commitments for science and technology should rise to at least 1 percent – preferably 1.5 percent – of Gross Domestic Product for each developing nation, and should be disbursed using a merit-based approach.



Independent scientific advice improves decisionmaking for public policies. The effectiveness of government programs can be greatly increased if they are subject to independent review by scientific and engineering experts – honest brokers who bridge the gap between what is technically possible and politically achievable in areas such as agriculture, education, energy, environment, and health. Each country therefore needs to create open and reliable mechanisms for providing impartial scientific and technological advice to government policymakers.

- Each national government should establish trusted indigenous mechanisms for obtaining advice on scientific and technological questions related to policies, programs, and international negotiations.
- Each nation involved in the development, production, or use of new technologies, such as those deriving from biotechnology, should have the means to assess and manage their benefits and risks. Governments should therefore ensure that indigenous S&T capacities are in place (with international inputs when necessary) not only for effective adoption of a new technology, but also for help in implementing public-health, human-safety, and environmental guidelines or regulations that address potential side-effects of the new technology. The possibility of long-term effects should be kept in mind when setting up such systems, which must remain fully adaptable to rapid advances in scientific and engineering knowledge.
- The coordination of such efforts among nations to permit the sharing of experience and the standardization of some types of risk assessment is highly desirable.

The public requires dissemination of new knowledge for addressing critical issues. Through the global system that the S&T community is creating on the Internet, local investigators can stay up to date on, and participate in, cutting-edge research. And because these indigenous professionals generally understand their nation's culture and can easily communicate with its people, they are uniquely placed to be disseminators of advanced knowledge and know-how to other critical local actors, ultimately increasing the likelihood that new technologies will be well adapted to that society's needs and cultures. Any nation without such a core of local scientists and technologists will be at a severe disadvantage.

- With the help of the S&T communities, each national and local government should encourage innovation in disseminating the results of publicly funded research and in turning them into new products and services that address local needs.
- Each nation's media should assume major responsibility for educating the public in S&T-related issues.
- A wide array of communications technologies – print, television, radio, cellular telephone, World Wide Web, the Internet, among others – should be utilized in disseminating to the public the results and public policy implications of publicly or privately funded research that addresses national or local needs.

Chapter 3: Expanding human resources

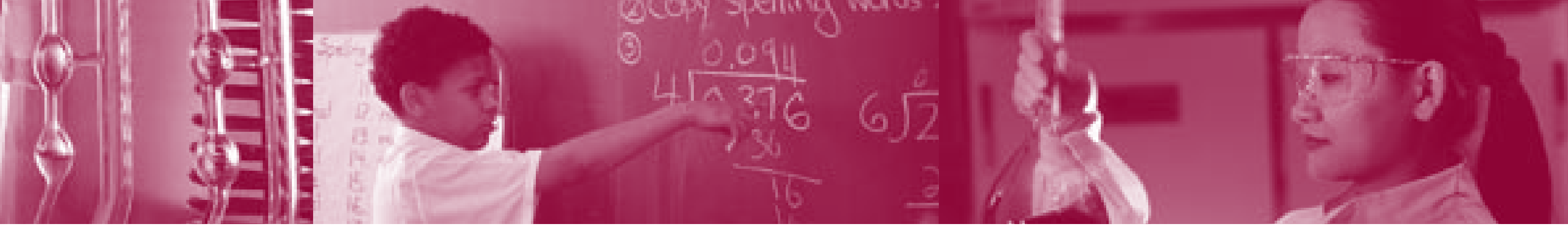
High-quality education and training are essential in all nations. Because so many of the urgent problems facing humanity today have potential solutions derived from science and technology, it is vital that science and technology become part of the mainstream of the education system. Courses providing the basis of S&T literacy and reasonable familiarity with scientific and technological culture should be required at all levels and for all students, including the many who do not intend to specialize in science or engineering. This can only occur if S&T literacy and culture are imparted in ways that capture the interest and imagination of young learners. But education will not achieve that quality unless the number of teachers knowledgeable in science and technology, and the quality of their education, are increased first.

- Each nation should establish an S&T-education policy that not only addresses its own particular national needs but also instills an awareness of global responsibilities in such areas as environment, human health, and the sustainable use of the earth's resources. National education policies should particularly aim to modernize education at the elementary- and secondary-school levels (ages 5-18); and they should emphasize inquiry-directed learning of principles and skills while highlighting the values of science.

- Each government should focus resources on providing high-quality training for science/technology teachers. This will involve special efforts at all tertiary-education institutions, including research universities.
- Science and engineering academies and other S&T organizations should be involved in teacher training and the production of materials needed for students' S&T education. Scientists should be encouraged to visit schools at all levels to make well-designed presentations that promote science to the young. The Inter-Academy Panel (IAP) and many national academies are already engaged in such activities, and results of their experiences should be widely disseminated. The private sector also should play an active role in promoting S&T education, as it will greatly benefit from a more sophisticated workforce. Foundations and nonprofit donors could find this a most deserving area of investment as well.
- Each government should stimulate the organization of national science olympiads in different areas of knowledge, at several levels of primary and secondary education and the first year of higher education, providing resources to enable the best young talents to participate in regional and international competitions.
- Each industrialized-country government should expand its support for S&T professionals and doctoral programs in the developing nations' best universities by offering long-term fellowships with adequate stipends to deserving young people from industrialized nations who wish to do their training in world-class research programs in developing nations. Visiting professors from foreign countries should help raise the quality level of courses and research, and participate in exams and thesis defenses. Meanwhile, all universities in developing nations should strengthen their undergraduate- and graduate-degree programs in science and technology and offer fellowships to the best students.

Developing nations should develop, attract, and maintain S&T talent. Many countries, especially the developing nations, suffer from two severe human-resource shortages: the lack of highly qualified scientists and engineers at universities and other research institutions; and a dearth of well-trained S&T teachers in the colleges and secondary and primary schools. A major reason for these persistent problems is the difficulty of keeping locally trained talents at home, as well as attracting home those individuals who have obtained their degrees at foreign institutions. This is the so-called 'brain drain' issue, and it is a serious impediment to building and sustaining indigenous human resources. The issue is dramatic enough to deserve much more attention from governments, academies, and international agencies; and it is important that reliable global statistics and trends related to the issue be compiled regularly by some of these institutions.

- Governments of all countries, particularly the developing ones, should seriously consider providing, even on a temporary basis, special working conditions for their best S&T talents (whether formed at world-class research programs abroad or at home), including income supplements and adequate research support. These programs should primarily focus on young scientists and engineers, enhancing future leadership for a new era of science and technology in the country, which could ultimately improve working conditions for all of its scientists and engineers.
- Governments of developing nations, in collaboration with their national S&T communities, should establish ties with their expatriate scientists and engineers, especially those who are working in industrialized nations.
- Governments and private institutions in industrialized nations provide incentives for outstanding young researchers from developing nations to apply their skills in the service of their native lands. Recipient countries and international institutions should create or enhance programs that link these talents with efforts to develop S&T capacities back home.
- Incentives should be established to help encourage companies, especially in the developing world, to create in-house research units and hire S&T talent. Local governments could give them tax rebates or national recognition for building their human-resources capacity in science and technology (through internship programs and contracted research). More broadly, a national strategic policy to promote research and development in a country's industries, including the provision of 'sectoral' funds, should be established.



- The S&T community should develop outreach programs for young girls and women to increase their participation in science and technology.
- Special outreach and support programs should be promoted by the S&T community for assuring ethnic, gender, and cultural diversity. Such programs should apply to all phases of the 'pipeline,' from early childhood through graduate school and into professionals' working lives.
- Appropriate international organizations should compile reliable global and national statistics documenting trends in the international migration of scientists and engineers.
- National governments and international organizations should provide the financial support and design the institutional framework to establish university 'sandwich programs' that provide for study in, and return from, a more advanced S&T country.

S&T capacity building is a shared regional and global responsibility. Leading research centers in the more advanced of the developing nations should play a fundamental role in building S&T capacity, both regionally and worldwide. Given their firsthand experience in overcoming many of the developing nations' typical difficulties, they are natural centers for spreading knowledge and skills to their neighbors. They should therefore commit themselves to this new enterprise by providing scholarships and opening their laboratories to talented young researchers from other developing nations.

- Regional cooperation in science and technology training that leads to doctoral degrees, together with postdoctoral programs, should be promoted in national or regional 'centers of excellence', especially those that are in S&T-proficient countries among the developing ones. In particular, such centers of excellence should provide scholarships and research facilities, including the use of their own laboratories, to help achieve international cooperation with and among developing nations. They should also take into account the often-critical need for travel money. Bilateral agreements between S&T-advanced and S&T-proficient countries should also allow for participation of scientists and engineers in neighboring S&T-developing and S&T-lagging countries.
- S&T-advanced nations should create programs that establish short-term adjunct-faculty/research positions at some of their universities and laboratories for scientists and engineers from developing nations.
- Networks that have already been established in diverse specialties should aid in the training of new scientists and engineers. These networks should be given enduring support by academic, governmental, intergovernmental, and private organizations.
- Several programs and fellowships to support S&T capacity-building activities have previously been established by some countries and by organizations such as UNESCO, the Third World Academy of Sciences (TWAS), International Centre for Theoretical Physics (ICTP), and International Council for Science (ICSU). A database of all such activities should be created and posted on a Website, thus making the information available to all scientists and engineers, even those working in the remotest regions of the world.

Digital libraries of science and technology can bring knowledge to virtually everyone, everywhere. Scientists and technologists in developing nations have limited access to recent research findings (mostly in journals), to reference materials (mostly in libraries elsewhere), and to databases (some of which are proprietary); and these problems have been exacerbated in the last decade as information streams turned into torrents. The enormous advances in information and communications technology have opened up opportunities for remedying the situation as never before, though these same advances have also raised issues of intellectual property rights. The proper harnessing of digital technologies is essential to S&T capacity building in the developing nations, which should make major efforts to provide adequate infrastructure and trained technical personnel in information and communications technology for their learning and research institutions.

- Information needed to promote and build S&T capacity – subscriptions to professional journals, for example, and textbooks – should be made available on the World Wide Web for free, or at modest cost, to scientists and engineers from developing nations. The InterAcademy Panel (IAP), International Council for Science (ICSU),

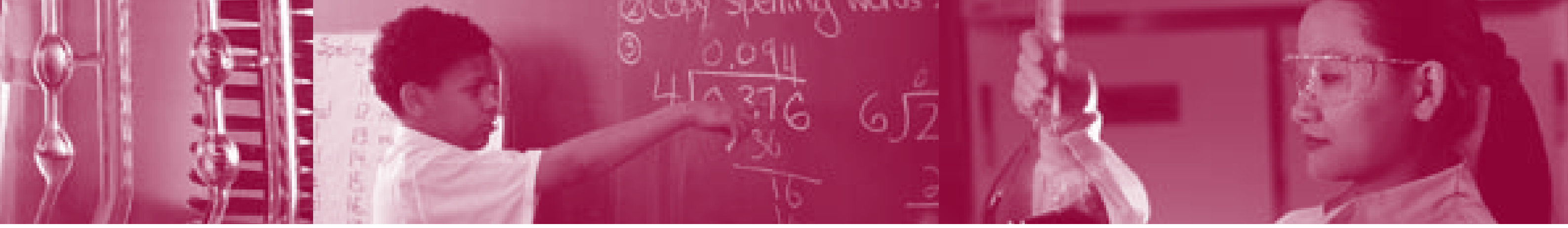
UNESCO, World Bank, regional development banks, and foundations should all promote this fundamental objective.

- Efforts to provide digital copies of current and back issues of scientific and engineering journals should be intensified, and the full range of these materials gradually posted for free, or at modest price, and universal access, with a focus on reaching S&T professionals in developing nations.
- The print journals presently publishing should be encouraged to post selected articles in electronic form concurrently with their paper publication; and to reduce the time between the appearance of the latest issue of the journal and its posting.
- A major international effort should be supported to ensure that a digital-format basic-science library is made available to libraries in developing nations.
- As much as possible of the scientific, engineering, and medical literature should be put in digital form on the World Wide Web for access from remote areas. In that spirit, new approaches should be explored for replacing copyrights with more suitable ways of protecting intellectual property rights and rewarding innovators, while supporting the public interest in having broad and rapid access to knowledge.
- Major hubs in the developing world should be organized for sharing digital information with research institutions in the regions and in the industrialized world. This will facilitate access to some materials (in video format, for example) that require a wide bandwidth not necessarily available everywhere. It will also serve the eminently sensible goal of backing up original material.
- Libraries should maintain electronic gateways for the sharing of digital information among researchers, teachers, and learners.
- Interlibrary loans in electronic form should be encouraged in the interests of efficiency and effectiveness. Various ways to ease fears of excess copying, from using established conventions to self-limiting or time-bound software, should be explored.

Chapter 4: Creating world-class research institutions

Autonomous centers of excellence address local challenges. Science and engineering advance largely at 'centers of excellence' – physical locations where research and advanced training are carried out, often in collaboration with other centers, institutions, and individuals. Centers of excellence are the key to innovation, and their importance cannot be overestimated. For the S&T capacities of developing nations to grow, therefore, they too should have centers of excellence – whether of local, national, regional, or international status. These centers of excellence do not necessarily have to be created de novo. The bolstering or reform of a country's most promising existing research and development programs can achieve the desired outcome. A key to promoting excellence is a merit-based allocation of resources based on rigorous review, in both deciding on new research projects and evaluating current programs. Given the relatively modest scientific capacity of most developing nations, such reviews should ideally include appropriate experts from other nations.

- Centers of excellence – whether of local, national, regional, or international status – should be created, or seriously planned for the near future, in practically every developing nation in order for its S&T capacity to grow. Such centers can serve as the main nodes for individuals or groups charged with enhancing S&T knowledge of national and regional importance.
- The centers of excellence should have institutional autonomy; sustainable financial support; knowledgeable and capable leadership; international input; focused research agendas that include interdisciplinary themes, applied research, as well as basic research; technology transfer; peer review as a systemic element; merit-based hiring and promotion policies; and mechanisms for nurturing new generations of S&T talent.
- Where such institutions already exist, they should be reinforced or, if necessary, reformed. When reform is indicated, changes should be systemwide and carried out in ways that make the best use of scarce resources (including the local talent).



- New scientific and technological research projects should be decided on the basis of input from expert review, with each project and program evaluated both for technical merit and for its potential benefits to society. All existing research programs and centers of excellence can similarly benefit from periodic expert review and evaluation. Techniques for such procedures should include, as appropriate, peer-review teams, relevance-review panels, or benchmarking studies.
- Given the relatively modest scientific capacity of most developing nations, their merit reviews should ideally include appropriate experts from other nations. Such involvement of the global research community, possibly through a program of international cooperation among academies of science, engineering, and medicine, can make the merit-review processes in developing nations more effective – not just for particular programs, but in general.

Strong universities are critical for expanding national S&T capacities. The role of universities in the development of S&T capacities cannot be overstated. Universities educate and train new generations of S&T talent, perform research and development on issues of importance to the nation, and provide an independent source of information on such topics as economic development, agriculture, health, and the environment. National governments in developing nations should make a clear, continued commitment to support and encourage advanced education and research activities within universities, in partnership with independent research institutes and industry. Without an explicit national commitment to strengthening universities, the goals of attaining a critical national capacity in science and technology cannot be achieved.

- National and local governments in developing nations should strengthen higher education with public funds (supplemented with private funds if available) to offer greater opportunities for tertiary education and S&T training to young people in modalities ranging from 'community colleges' (as they are called in the United States) to top-class research-based universities.
- National and local governments in developing nations should develop strong partnerships with universities and industry to plan the development of capabilities in science and technology.
- Universities should have increased autonomy while seeking to systematically strengthen their ties with regional and international institutions and networks; such links can significantly increase the effectiveness of the universities' S&T efforts.
- Research universities should make strong commitments to excellence and the promotion of the open, honest values of science in their activities, incorporating unbiased merit reviews into all of their decisions on people, programs, and resources; they should also have greater interaction with society at large.

Virtual networks of excellence link the scientific talents of entire regions and the globe. An important step toward building centers of excellence will be the creation of 'virtual networks of excellence' (VNE), extending throughout the developing world, with the primary objective of nurturing scientific and engineering talent in mostly 'virtual institutes'. These entities should be relatively small and efficient, and embrace innovative research groups that may be far apart geographically but closely linked via the Internet and anchored in recognized research centers. The virtual institutes created through virtual networks of excellence will work to blend their activities into coherent programs, yet the individual research groups will work in areas of prime interest to their own countries. Successful examples are the Millennium Science Institutes created in several countries by the Millennium Science Initiative with the support of the World Bank.

- Virtual networks of excellence (VNE) – research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the Internet and the World Wide Web, deemed by merit-review to be of the highest international quality in personnel, infrastructure, and research output – should be created nationally, regionally, and globally.

National academies of sciences, engineering, and medicine can improve the quality of national S&T programs. National academies as understood here are member-based autonomous institutions, motivated by their commitment to scientific, engineering or medical excellence, in which peers elect new members, elect their officials, and execute agreed-upon work programs for decision-makers in government. The presence of such institutions is extremely important for upholding the quality of S&T activity in a country, for guiding national policies based on science and technology, and for maintaining dialogue with other countries, often through their counterpart academies.

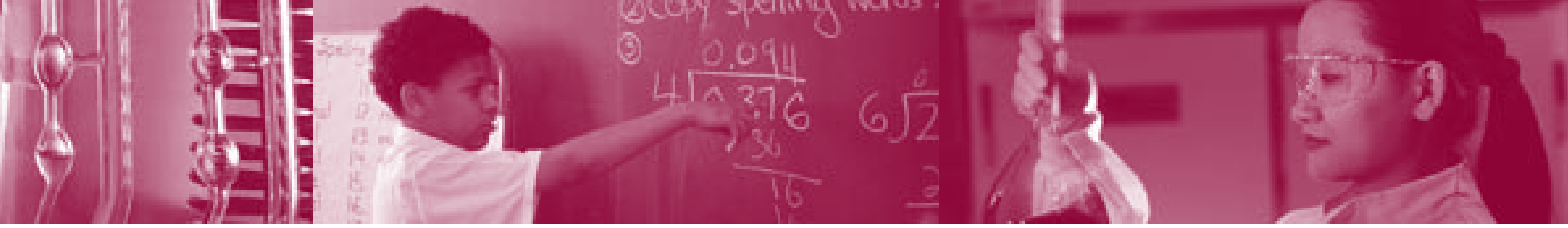
- Every country should have national academies of sciences, engineering, and medicine – member-based autonomous institutions, in which peers elect new members in recognition of their distinguished and continuing professional achievements, elect their own officials, perform programs of independent work, and inform the general public and national decisionmakers on science and technology aspects of public policies.
- For those countries without a critical mass of active scientists or engineers, the creation of national academies may not be possible. In such cases, academies should be built on a regional rather than a national basis. The formation of professional societies should also be promoted.
- International institutions, such as the Third World Academy of Sciences (TWAS), InterAcademy Panel (IAP), International Council for Science (ICSU), Council of Academies of Engineering and Technological Sciences (CAETS), and InterAcademy Medical Panel (IAMP), should continue to facilitate the formation and strengthening of nascent national and regional academies of sciences, engineering, and medicine. The forceful participation of these international bodies will help new organizations establish the requisite high standards and effective mechanisms of operation.
- Academies should actively participate in national and international debates to make the voices of the S&T community heard on a broad range of issues.

Chapter 5: Engaging the public and private sectors

Clear legal frameworks promote successful public-private interaction. It is essential to recognize that for the private sector to best contribute to the development of S&T capacity, the public sector should maintain an enabling environment – local, national, international. Governments should provide regulatory frameworks to protect the public interest and safety, and fund research and development efforts for public goods. Because these roles interact in complex ways, and can sometimes clash, it is important to define a framework for the public-private interface so that each party is sufficiently aware of its domain's boundaries and where it may overlap with that of the other.

- Every country should develop a clear legal framework regarding the activities of the private sector in S&T capacity building, and it should be compatible with the national S&T policy while providing incentives for real technology transfer. Recognizing that there is no single formula – every country, in every field, has certain specifics – such a framework should include the following:
- Definition of the scope of the public domain and the maintenance of public spending for public-goods research.
- Definition of the boundaries of the public-private domains so as to take maximum advantage of the complementarities and reduce the overlaps.
- S&T-developing and S&T-lagging nations should consider regional and multilateral cooperation and sharing of resources for implementing intellectual property protection, so that poor countries with limited technical resources do not have to duplicate effort, investment, and dedication of scarce talent.

Public-private partnerships are critical if science and technology are to benefit society. To bring the benefits of scientific discoveries and technological innovations to all of the world's people, imaginative and vigorous forms of public-private collaboration should be actively promoted. Such partnerships can invigorate education, conduct research of mutual interest, and capitalize on the results of the research for the citizenry's benefit. But because it



has not traditionally been in the self-interest of private companies to share their resources and creative competencies with the public sector, incentives are needed to encourage them. This can be accomplished through a variety of means, including tax advantages to firms for cooperative research, commercialization of publicly financed research, 'scientist-in-industry' programs, joint or specialized training, and technology parks and 'incubators.'

- Governments, industries, universities, and research institutes in developing nations should experiment with partnerships and consortia for addressing research areas of potential local benefit.
- Governments in particular – both national and local – should play a central role in creating public-private research partnerships.
- National and local governments should ensure that individuals and organizations continue to have strong incentives and opportunities to capitalize on research.
- Participants should ensure that public-private research relationships do not impair the core mission and values of public research institutions.

The international private sector sponsors S&T research that has great potential for addressing challenges in developing nations. New areas of knowledge, rendered explorable with the aid of new technologies (particularly information and communications technology), are opening up in areas such as the biological sciences. Driven by this research and development, mostly in the wealthy nations, new and exciting commercial applications across the globe – particularly important to S&T-lagging nations – are likely not only in medicine and agriculture but also in environmental protection and other critical areas. Many of these opportunities could be realized and problems solved with the advent of a favorable intellectual property regime, which the international private sector depends on to recoup its investments in research and development. Yet it is also increasingly clear that the current system of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) is not necessarily beneficial to the developing nations. Thus some judicious changes within TRIPS are in order to protect their interests while respecting the interests of the innovators.

- Governments of developing nations should focus on licensing issues, accept strong intellectual property rights for new medicines, negotiate special agreements on generics for basic pharmaceutical products, promote local industry through partnerships with foreign companies, and amend their current intellectual property legislation to emphasize the genuine invention of useful technologies while putting less focus on the protection of minor or intermediate technologies and research and development processes.
- Governments of industrialized nations should offer research grants for poor-country diseases, promote global health initiatives, provide tax incentives to major companies for working with developing nations and for doing automatic licensing and other initiatives, and they should support the extension of the grace period under the Agreement for Trade-Related Aspects of Intellectual Property Rights (TRIPS) to 2016 for most developing nations.
- The multinational private sector based in the S&T-advanced countries should waive patent fees on the few existing patented tropical-disease drugs, and make them available for free in some cases. It should allow automatic licensing for S&T-proficient and S&T-developing countries to produce generic drugs (as long as they honor a ban on exportation of the generics to the high-income markets of the industrialized nations). And it should build real partnerships with developing nations' private sectors, consider market segmentation for the developing world, and actively encourage extensions of the grace period under the Agreement for Trade-Related Aspects of Intellectual Property Rights (TRIPS) to 2016 for most developing nations.
- The national academies should become more actively involved in bringing together the private and public sectors; and they should work across sectoral and national boundaries to help promote collaboration between the industrialized and developing nations, as well as among the developing nations. Scientists and engineers can play especially productive roles here in articulating creative proposals for different countries and sectors, making available intermediate inputs in research, access to digital information online, and wide bandwidth links between public research facilities and the new digital libraries of the future.

Chapter 6: Targeted funding of research and training efforts

The Study Panel believes that the overall levels of all official development assistance should be increased, and that the place of S&T capacity building should be secured among the priorities. Many existing programs for fellowships, training, and education can be expanded, as can programs of support for universities in developing nations. In addition, there are many innovative approaches being explored in the domain of international funding for development. Debt-swaps, involving either foreign loan principal or interest, already used in terms of debt for nature swaps, could also be explored for S&T capacity building, as could some of the debt relief programs for the heavily indebted poorest countries – helping them to address the special recommendations for these S&T-lagging countries. Out of many other possibilities, the Study Panel has selected the following suggestions for further elaboration.

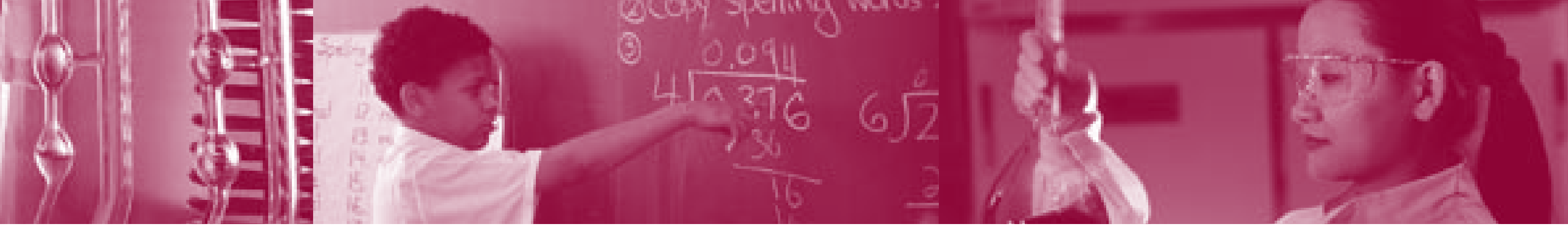
National 'sectoral' funding programs provide support for research and development of national importance. One of the most imaginative ideas for national funding of research and development is the concept of 'sectoral' funds – a portion of a nation's tax levies on for-profit corporations redirected into a special fund for financing the conduct of research in selected S&T areas of economic interest to the nation. Sectoral funds, which can help implement a national strategic policy to promote high-quality research and development in a country's industries, require close interaction of the indigenous academic community, private sector, and government in creating the funds, setting their priorities, and managing them. Decisions on the selection of strategic sectors, their respective shares of the fund's resources, the blend of basic and applied research, the required overall budget, and sources of support are all jointly made.

- The option of national sectoral funding for research and development should be seriously considered by the public, private, and academic sectors of developing nations that aspire to significant S&T capacity.
- The management of each sectoral fund should be tripartite, with the participation of the academic community, government, and industry. A portion of each fund's resources should be used to support basic science, and another portion should support infrastructural needs.

Regional S&T networks should share responsibility for funding research. Beyond the S&T-advanced Australia, Canada, Japan, South Korea, the United States, and northern and western Europe, there are S&T-proficient countries among the many S&T-lagging ones in every region of the world. Regional networks, through which neighboring developing nations could together pursue world-class research and training activities on issues of mutual concern, should be created and supported in order to complement sectoral funds. The regional networks could in turn be involved in cooperative programs with S&T-advanced countries. These countries should be willing to fund these networks, along with the international-donor and financing community.

- The S&T-proficient countries should cooperate with S&T-lagging countries in world-class research and education through regional networks.
- Research nodes of the networks should be recognized centers of excellence in developing nations with a strong research base; this connection would help catalyze the strengthening of S&T capacities among their less-developed partners.
- The networks should stimulate interdisciplinary research and establish links with the member countries' private sectors.

Global funding mechanisms should be strengthened for support of science and technology in developing nations. While the possibility exists for such funding through the targeted sectoral funds discussed above, it would require exceptionally committed governments. In some places, the total resources available may be insufficient for generating the needed foreign-currency resources. Therefore the Study Panel suggests that two global funds – an institutional fund and a program fund – be set up in a consultative process. Such global funds would not have to be pooled but could remain distinct, though coordinated centrally, so as to allow those donors with particular restrictions to honor them while still participating in a coordinated funding plan.



- A *Global Institutional Fund* should be established to provide 'soft funding' over a period of 5 to 10 years to some 20 centers of excellence of a national or regional character (operating by themselves or in developing-country networks). This funding would not be program-specific; it would be used instead to allow centers to promote the values of science and engineering and to create an atmosphere in which the practice of high-quality research can flourish. Specifically, the money would help each center to develop its programs, cultivate its management, and build its long-term funding base. Donors would meet in a consultative mode to review proposals resulting from an open call for competitive submissions, and they would select the centers according to clearly established evaluation criteria.
- A *Global Program Fund*, creating new partnerships with advanced research institutes, should be established as a competitive grants system – for support of research groups in centers of excellence in developing nations – in which international referees would review the quality of the projects being proposed. Preference would be given to proposals that involve groups in several local and regional institutions. However, bilateral proposals – from one recipient center in cooperation with a research institute in an S&T-advanced or S&T-proficient country – would be perfectly acceptable, given the benefits of their one-on-one focus and the relative simplicity of their objectives (together with the greater likelihood of meeting them).

Chapter 7: From ideas to impacts: coalitions for effective action

Urgent national and international actions can facilitate the strengthening of national science and technology. The four actions listed below are the initiating measures from which all else would follow; the other recommendations in this report – and the coalitions in different parts of the world that would implement them – will largely depend on the success of these urgent actions. As such, they should be undertaken immediately.

1. Strengthen national academies of sciences, engineering, and medicine, and the national S&T communities.
2. Mobilize the international S&T community.
3. Raise the level of public awareness.
4. Protect public goods and define the boundaries of the public/private interface.

New initiatives can help promote indigenous S&T capacity. The following set of recommendations, while not necessarily new to those involved in research and development, are nevertheless novel to much of the public at large. The Study Panel believes that their implementation could well make the difference between success and failure in building indigenous S&T capacity around the globe.

1. Attract, develop, and retain young scientists and engineers.
2. Provide S&T education at all levels.
3. Build centers of excellence.
4. Establish virtual networks of excellence.
5. Foster public-private partnerships that involve academia.
6. Strengthen links with expatriate scientists and engineers.
7. Create and maintain digital libraries.
8. Build regional networks of collaboration.
9. Devise novel funding mechanisms.

Some well-established measures deserve repeating. Beyond the innovative measures noted above, it is important to keep pushing for the adoption of certain measures that have been regularly discussed but insufficiently acted upon in the past. These include:

1. Develop national plans ('policy for S&T').
2. Provide expert scientific inputs to policymaking ('S&T for policy').

S&T-lagging countries urgently require regional and international collaboration. The recommendations advanced in this report are more generally suitable for industrialized nations and for those developing nations that have already achieved some sizeable measures of success in their national educational, training, and research systems. For some of the poorest and the smallest countries, some recommendations may not be

feasible. Thus the Study Panel emphasizes that they be pursued on a regional basis for such nations – i.e., in collaboration with neighboring countries – so that a critical mass of scientific capability can be achieved. These least-developed countries merit direct attention in this report in terms of 'South-South' and 'North-South' cooperation and of required commitments from the S&T-advanced and -proficient countries. The agenda for S&T-lagging countries should include the following actions:

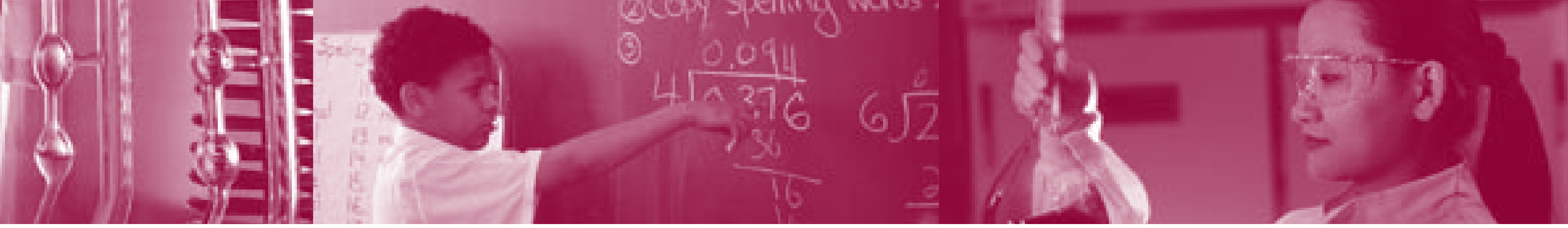
1. Identify national S&T goals and priorities.
2. Mobilize international expertise for promoting national capabilities in science and technology.
3. Orient S&T-capacity needs for achieving national goals.
4. Participate in regional or international centers of excellence that address issues of national need.
5. Establish mechanisms for S&T advice to government.
6. Provide information on S&T resources and issues to the public.
7. Upgrade educational programs and institutions.
8. Join regional and international S&T training programs.
9. Increase S&T career opportunities within the country.

A global 'implementation strategy' can lead to new S&T initiatives. It is essential that this report lead to real action: things really happen on the ground. To that end, the Study Panel proposes that the InterAcademy Council – in consultation with other relevant international and national organizations – develop an 'implementation strategy.' This implementation strategy should identify concrete actions for helping international, national, and local actors bring about reforms and introduce the necessary innovations, including:

1. Monitoring the implementation of programs.
2. Promoting action networks.
3. Acting as a clearinghouse for knowledge information and communications technology.
4. Mining the most useful S&T data, and rendering it more accessible.
5. Networking among the academies.

An international conference of financial donors can help develop new mechanisms for increasing S&T capacity in developing nations. Many of the proposals in this report require new or improved international procedures for funding science and technology within the developing nations. Such procedures should be developed by the international community of financial donors. A special kick-off conference of members of that community should be convened to review the proposals contained in this report and, if they agree to them, form a steering committee to develop the mechanisms needed for implementation. Organizations represented should include multilateral institutions, national governments, foundations, the for-profit sector, and nongovernmental organizations.

A better future is within our grasp. It is absolutely necessary for developing nations to strengthen their S&T capacity. And they must do so soon, through their own focused efforts, with help from their friends. Given the currently rapid rate of change in science and technology, there is no time to waste if the majority of humanity is not to suffer further marginalization. We must, by our actions from this day forward, lay down the foundations for better tomorrows, when the benefits of science and technology will reach the traditionally detached, include the excluded, serve the unserved, and give hope to every human being on our planet that he or she too has a chance to live in dignity, comfort, health, and happiness. If we truly believe in our common humanity, we must aim for no less.



Agendas for major actors in building science and technology capacity

To build worldwide S&T capacities, all major institutions should actively work together to:

1. Foster a global mobilization to create a better future for humanity.
2. Convene a kick-off conference to launch, review, refine, and initiate the implementation of the set of proposals presented in this report.
3. Convene regional and national conferences to review, refine, and initiate the implementation of the set of proposals presented in this report.

Each type of institutional actor will have different roles and responsibilities in this effort. The Study Panel has identified twelve major actors and the action agenda required of each them to implement the needed reforms and new programs for increasing worldwide scientific capacity.

S&T-proficient and S&T-developing countries

1. Identify national science and technology goals and priorities.
2. Assess strengths and weaknesses of current S&T capacity for achieving goals.
3. Establish a government-university-industry partnership for strengthening S&T capacity.
4. Create centers of excellence that address issues of national need.
5. Upgrade ongoing research programs that address issues of national need.
6. Establish mechanisms for S&T advice to government.
7. Provide information on S&T resources and issues to the public.
8. Upgrade educational programs and institutions.
9. For S&T-proficient countries, share responsibilities for regional and international S&T training and research programs.
10. Increase S&T career opportunities within the country.
11. Develop digital S&T information sources.
12. Develop effective policies for intellectual property rights.

S&T-lagging countries

1. Identify national science and technology goals and priorities.
2. Mobilize international expertise for promoting national capabilities in science and technology.
3. Orient S&T capacity for achieving national goals.
4. Participate in regional or international centers of excellence that address issues of national need.
5. Establish mechanisms for S&T advice to government.
6. Provide information on S&T resources and issues to the public.
7. Upgrade educational programs and institutions.
8. Join regional and international S&T training and research programs.
9. Increase S&T career opportunities within the country.

S&T-advanced countries

1. Support research and development efforts in developing nations that address local and global needs.
2. Share information and experiences in benefit/risk assessments of new technologies.
3. Support the education and training of S&T professionals in developing nations.

United Nations agencies and regional intergovernmental organizations

1. Help developing nations to identify national S&T goals and priorities.
2. Support research and development efforts in developing nations that address local and global needs.
3. Help developing nations to upgrade their educational institutions and programs.
4. Help developing nations in providing information on S&T resources and issues to the public.
5. Facilitate regional and international S&T training programs.
6. Support the development of digital S&T information sources.

Educational, training, and research institutions

1. Participate in national efforts to identify national S&T goals and priorities.
2. Assess strengths and weaknesses of universities and research institutions for achieving national S&T goals.
3. Establish partnerships with government and industry for strengthening S&T capacity.
4. Create centers of excellence that address issues of national need.
5. Upgrade ongoing research programs that address issues of national need.
6. Upgrade educational programs and institutions.
7. Sponsor and participate in regional and international S&T training programs.
8. Provide information on S&T resources and issues to the public.

National academies of sciences, engineering, and medicine

1. Participate in national efforts to identify national S&T goals and priorities.
2. Help the government to assess strengths and weaknesses of national capacities for achieving national S&T goals.
3. Provide S&T advice to the government.
4. Encourage new centers of excellence that address issues of national need.
5. Promote the upgrading of ongoing research programs that address issues of national need.
6. Promote the upgrading of educational programs and institutions.
7. Provide information on S&T issues of importance to the public.

National, regional, and international S&T organizations

1. Facilitate the effectiveness of research programs in developing nations.
2. Participate in providing scientific advice to developing-nation governments on scientific questions related to public policies and programs.
3. Help developing nations to upgrade their educational institutions and programs.

International development-assistance organizations

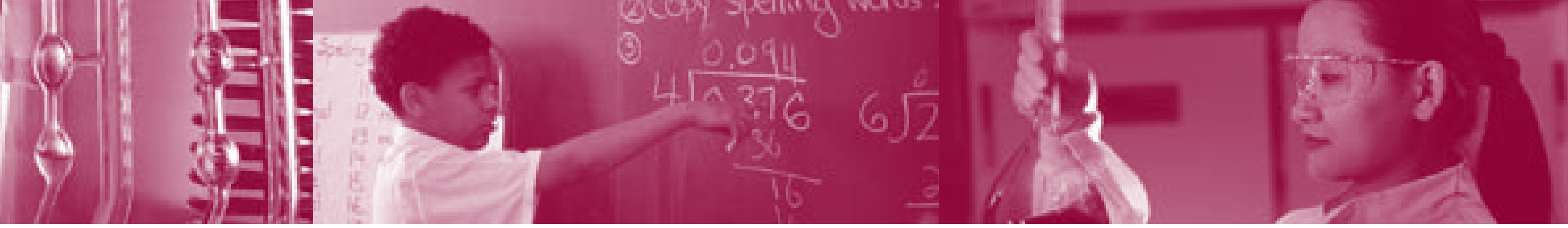
1. Help developing nations to identify national S&T goals and priorities.
2. Support research and development efforts in developing nations that address local and global needs.
3. Help developing nations to upgrade their educational institutions and programs.
4. Help provide information on S&T resources and issues to the public.
5. Help promote public-private partnerships.
6. Facilitate regional and international S&T training programs.
7. Support the development of digital S&T information sources.

Foundations

1. Support research and development efforts in developing nations that address local and global needs.
2. Help developing nations to upgrade their educational institutions and programs.
3. Help developing nations to provide information on S&T resources and issues to the public.
4. Facilitate regional and international S&T training programs.
5. Support the development of digital S&T information sources.
6. Play an important role in implementing the actions proposed in this report, either individually or in partnerships with national governments; private sector; and international, regional, and local agencies.

Local, national, and international private sectors (for-profit entities)

1. Participate in national efforts to identify national S&T goals and priorities.
2. Support research and development efforts in developing nations that address local and global needs.
3. Participate in government-university-industry partnerships for strengthening S&T capacity.
4. Help developing nations to upgrade their educational institutions and programs.
5. Help provide information on S&T resources and issues to the public.



Nongovernmental organizations

1. Encourage innovation in disseminating the results of research and in turning them into new products and services that address local needs.
2. Provide information to the public about S&T issues relevant to developing nations.

The media

1. Assume major responsibility for educating the nation's public on S&T-related issues.
2. Use the new electronic media to provide the public with information related to issues of science and technology.

1. The urgency to promote worldwide science and technology capacity

1.1 The world is changing at a rapid pace, driven by science and technology

The countless manifestations of science pervade our world, and they profoundly affect the social, economic, and cultural outlooks of societies and individuals alike. Moreover, the accumulation of scientific knowledge and its technological applications is accelerating at a dizzying clip, enabled in large part by ever more powerful computers and lightning-fast communications.

The Internet, for example, revolutionizes the very meaning of time and space. With the click of a mouse and the flight of electrons, vast quantities of data and manifold services can move across the globe. Today there are billions of pages on the appropriately named World Wide Web; by 2005 it will likely be eight billion. Thus the integration of the world economy through trade, capital flows, and enhanced communications is rapidly proceeding as the products of the Information and Communications Technology Revolution permeate every corner of society. The economies of the world will increasingly become 'knowledge-based,' with value-added coming more from knowledge than materials.

A revolution is occurring in the life sciences as well. Today we are not only decoding DNA – the blueprint of life – we are learning to manage the placement and expression of genes and to mobilize microorganisms to do our work. We can thereby manipulate – repair, transfer, insert – the constituents of living things in order to improve health, create new and useful products, increase productivity, and even transform whole industries.

Taken together, such innovations have altered and expanded our notions of economic and social development, and they often do so not with high-tech dazzle, but in mundane yet profound ways. We have come to realize that better health care, nutrition, and labor-saving devices make it possible for more young people to attend school and to complete more years of schooling. The net result, at least in some societies, has been a major increase in the number of able and educated individuals entering the workforce – people who have far better prospects of contributing to the overall welfare of society and of leading more satisfying lives.

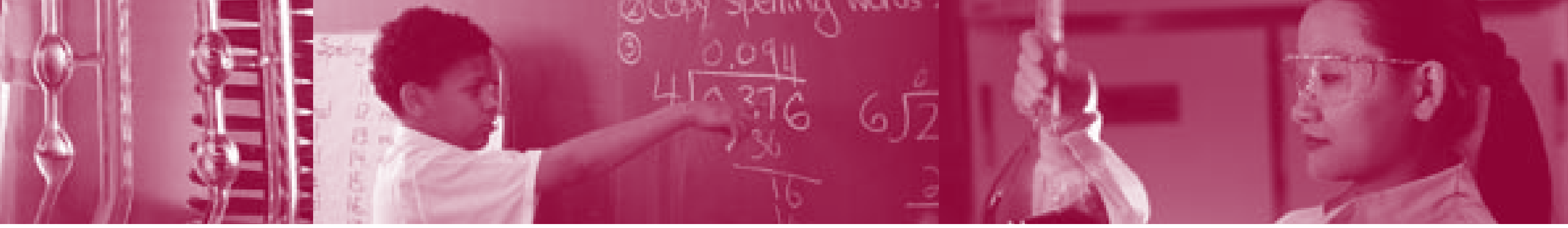
Yet the global reality is that many innovations fail to accrue to those who need them most, and benefits are not shared equitably around the planet. Such maldistribution is further confounded by troubling trends in demography, urbanization, public health, and environment, which will continue into the foreseeable future even if only from their present momentum.

Demographic growth will continue until the world population stabilizes at between 8 and 9.5 billion persons by the middle of the century, with enormous differences in the age profiles of different parts of the world. Sub-Saharan Africa, for example, will continue to grow, likely reaching some 1.5 billion persons. Conversely, in Japan and most of Europe, populations will remain stable if not actually decline. The industrialized nations will increasingly see the graying of their labor forces and an increase in the needs of the elderly, with concomitant shortages in rapidly growing parts of their labor market; by contrast, the predominantly young populations of the developing nations will be putting enormous pressure on education and training facilities and on local labor markets to create adequate employment opportunities.

For the first time, the majority of human beings are now classified as urban, a phenomenon that will continue unabated, mostly in the developing world, even though some will use the new information and communications technology to work out of more rural surroundings. Urbanization will challenge the capacities of developing nations to deal with the enormous problems of their 'megacities' (those with populations over 10 million). Over the next three decades, India alone will face an increment of urban population twice the size of the total populations of France, Germany, and the United Kingdom combined.[1]

Poverty, destitution, and hunger still stalk humanity. Despite the enormous improvements that have been achieved in human welfare, 38 percent of the people in the least developed nations are malnourished and the shadow of starvation and famine still looms large in parts of the world – especially in Sub-Saharan Africa, where civil strife has exacerbated an already bad situation. One-sixth of the human family lives on less than a dollar a day, and almost half of humanity survives on fewer than two dollars a day. The richest quintile of the world's people earns more than 70 times the income of the poorest quintile.[2]

Problems such as HIV/AIDS strike globally, though responses to the disease's devastation vary enormously with a nation's capacity to deliver treatment and modify societal behavior. Some societies are producing a generation of AIDS orphans, with large parts of Sub-Saharan Africa and South Asia facing enormous and crippling losses. The decimation of young adults at their most productive moments is a human tragedy of gigantic proportions and a social and economic nightmare. Dramatic policy changes



are required to address this issue, as well as persistent diseases such as malaria and tuberculosis and the more recent threat of severe acute respiratory syndrome (SARS). More research is required to find better responses. Scientific collaboration on confronting the challenge – and on making the results of the research available to those who need it most – is essential.

Environmental challenges abound. If present production and consumption patterns are not changed, the impact on our biosphere will be astounding: the air and water we depend on will become increasingly polluted; the soils will more and more erode; and forests, habitats, and biodiversity will continue to be lost. If the entire population of the earth were to produce and consume at present U.S. levels, we would need three Planet Earths. The need to implement more environmentally friendly and socially responsible economic activity has never been greater.

Luckily, we have a growing level of international consensus today on these demographic, urbanization, public health, and environmental issues, among others, that has never before existed. In September 2000, the United Nations Millennium Summit of the world's heads of state declared specific goals for reducing poverty, hunger, illiteracy, disease, and environmental degradation. (See Box 1 on next page.) Explicit in these Millennium Development Goals is a commitment to equity and participation, rather than polarization and marginalization, as we move toward an increasingly knowledge-based economy in the 21st century. The need for international cooperation to address these concerns is also recognized in the United Nations Millennium Declaration, especially considering problems such as environmental issues, which cross national borders. (Box 2 on page 21 describes the science and technology needs identified in three recent international agreements – on climate change, biodiversity, and sustainable development.)

Yet despite the growing consensus on all these issues, despite agreement on the inevitability of movement toward a knowledge-based future, the international community has overlooked something critical. It has given inadequate attention to capacity building in science and technology (S&T) as the engine that drives knowledge-based development, that is essential to social and economical inclusion, and that alleviates the demographic, urbanization, public health, and environmental pressures plaguing the world – especially the developing world.

It is precisely the need to correct that critical omission that we address here, and we do so in terms of the needed personnel, infrastructure, investment, institutions, and regulatory framework available for conducting scientific research and pursuing technological development in every country of the world.

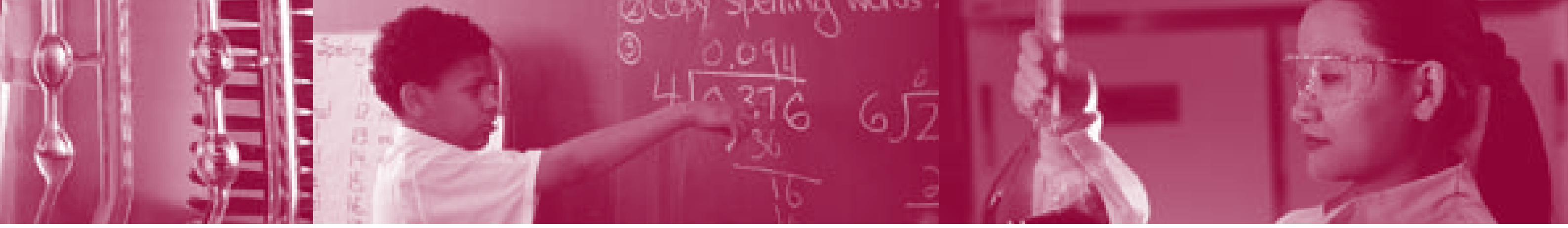
BOX 1 United Nations Millennium Development Goals

The Millennium Development Goals are an ambitious agenda for reducing poverty and improving lives throughout the world. World leaders agreed on these goals at the United Nations Millennium Summit in September 2000. For each goal, one or more targets have been set, using 1990 as a benchmark:

1. Eradicate extreme poverty and hunger:
   Target for 2015: Halve the proportion of people living on less than a dollar a day and those who suffer from hunger
2. Achieve universal primary education:
   Target for 2015: Ensure that all boys and girls complete primary school
3. Promote gender equality and empower women:
   Targets for 2005 and 2015: Eliminate gender disparities in primary and secondary education preferably by 2005, and at all levels by 2015
4. Reduce child mortality:
   Target for 2015: Reduce by two-thirds the mortality rate among children under five
5. Improve maternal health:
   Target for 2015: Reduce by three-quarters the ratio of women dying in childbirth
6. Combat HIV/AIDS, malaria, and other diseases:
   Target for 2015: Halt and begin to reverse the spread of HIV/AIDS and the incidence of malaria and other major diseases
7. Ensure environmental sustainability:
   Targets:
   - Integrate the principles of sustainable development into country policies and programs and reverse the loss of environmental resources
   - By 2015, reduce by half the proportion of people without access to safe drinking water
   - By 2020, achieve significant improvement in the lives of at least 100 million slum dwellers
8. Develop a global partnership for development:
   Targets:
   - Develop further an open trading and financial system that includes a commitment to good governance, development, and poverty reduction – nationally and internationally
   - Address the least-developed countries' special needs, and the special needs of landlocked and small-island developing states
   - Deal comprehensively with developing countries' debt problems
   - Develop decent and productive work for youth
   - In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries
   - In cooperation with the private sector, make available the benefits of new technologies – especially information and communications technologies.

Source: Resolution 55/2 adopted by the United Nations General Assembly, September 2000.

www.un.org/millenniumgoals/index.shtml



BOX 2 International agreements and S&T capacity

S&T capacity building in developing countries is a critical element for effective implementation of international agreements and protocols.

United Nations Framework Convention on Climate Change
Article 5, Research and Systematic Observation
"In carrying out their commitments..., the Parties shall: a) Support and further develop, as appropriate, international and intergovernmental programmes and networks or organizations aimed at defining, conducting, assessing and financing research, data collection and systematic observation, taking into account the need to minimize duplication of effort; b) Support international and intergovernmental efforts to strengthen systematic observation and national scientific and technical research capacities and capabilities, particularly in developing countries, and to promote access to, and the exchange of, data and analyses thereof obtained from areas beyond national jurisdiction, and; c) Take into account the particular concerns and needs of developing countries and cooperate in improving their endogenous capacities and capabilities to participate in the efforts referred to in subparagraphs (a) and (b) above."

www.biodiv.org

United Nations Convention on Biological Diversity, 1992
Article 12, Research and Training
"The Contracting Parties, taking into account the special needs of developing countries, shall:
a) Establish and maintain programmes for scientific and technical education and training in measures for the identification, conservation, and sustainable use of biological diversity and its components and provide support for such education and training for the specific needs of developing countries;
b) Promote and encourage research which contributes to the conservation and sustainable use of biological diversity, particularly in the developing countries..."

www.biodiv.org

World Summit on Sustainable Development, 2002
Plan of Implementation:
"125. Enhance and accelerate human, institutional and infrastructure capacity-building initiatives and promote partnerships in that regard that respond to the specific needs of developing countries in the context of sustainable development.
126. Support local, national, regional, subregional and regional initiatives with action to develop, use and adapt knowledge and techniques to enhance local, national, subregional, regional centres of excellence for education, research and training in order to strengthen the knowledge capacity of developing countries and countries with economies in transition through, inter alia, the mobilization from all sources of adequate financial and other resources, including new and additional resources."

www.johannesburgsummit.org

BOX

1.2 Business-as-usual will leave an ever-growing gap between 'have' and 'have-not' nations

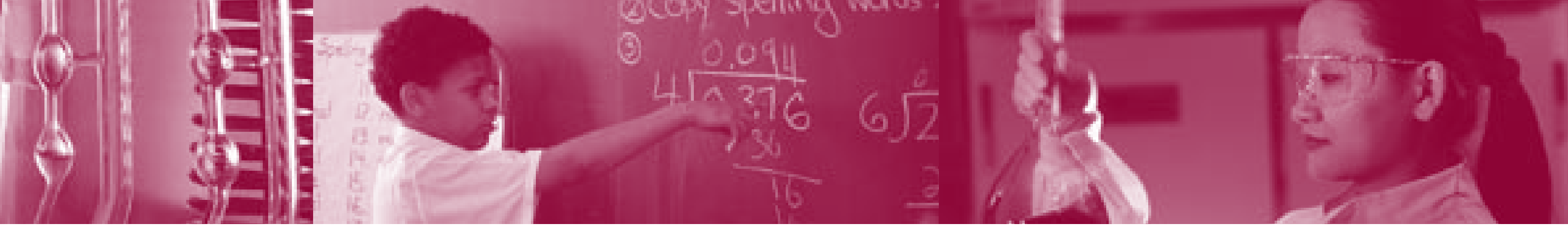
Under the impetus of strong forces of globalization, the world is today dominated by a market- oriented economy. But while many countries lack the policies or infrastructure to support market-oriented mechanisms for building their exports or their productive economic assets, not to mention their S&T capacity. While the specifics vary, there are points in common in many developing nations that enable the Study Panel to highlight in this report some areas of special attention.

The industrialized, S&T-advanced countries undoubtedly have concerns about balancing the public and private domains, improving the quality of their educational systems, attracting and retaining talent in S&T fields, or the manner in which national investments in research and development (R&D) can be optimized. Yet for the Study Panel, as it surveys the scene across the globe, it is clear that the starkest problem facing the world and the international scientific community is the large and growing gap between the industrialized nations and the less-developed countries. As we move toward a knowledge-based economy, some 80 percent of humanity are deprived of the opportunity to contribute to knowledge and instead are relegated to consumption of the resulting technology. Furthermore, many new technologies will not be consumable in developing nations without a powerful local capacity in the science and engineering that underlie them.

The industrialized nations have an interest in supporting the expansion of S&T capacity in the developing world. Their citizens cannot remain safe and prosperous in a world containing large numbers of failed states. Expansion of science and technology also helps in building markets, promoting stability, and enhancing trade. For the developing nations, creating the local capacity for enhanced cooperation with industrialized nations allows them to harness the best of science and technology to address many of the issues limiting their development, make use of their vast resources of indigenous knowledge (confirmed by rigorous scientific methods), reaffirm national pride in their own heritage and achievements, and chart a new course for a more sustainable development pattern. International cooperation is to the mutual benefit for all.

In addition, the more S&T proficient among the developing nations (Brazil, Chile, China, India, Mexico, and South Africa, for example) have the opportunity and responsibility not only to help themselves but to work with their brethren in other developing nations so that they too may build their S&T capacities.[3]

In effect, individual human development is now viewed as essential to each nation's – and the world's – long-term economic development. Technological advances – coupled with improved education and training



– lead to improvements in human capital, which in turn produce more and better goods and services. Along the way, this 'virtuous cycle' can promote free expression and public discourse, not necessarily out of altruism but as an economic imperative.

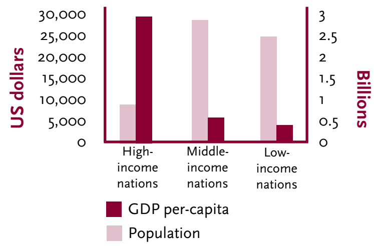
Yet, despite the remarkable results that scientific advances and technological innovations can potentially engender, these times are marred by conflict, violence, economic uncertainty, chronic deprivation and poverty, and far too many marginal, even threatened, lives. Although we know that science and technology can indeed help feed the hungry, heal the sick, protect the environment, provide dignity in work, and create space for the joy of self-expression, impoverished societies lack the wherewithal to apply them.

In fact, a *vicious* cycle is at work whereby the developing nations (especially the S&T-lagging countries) fall farther and farther behind the industrialized nations that do have the resources – in financial, as well as human-development terms – to apply scientific advances and new technologies ever more intensively and creatively. Numerous young professionals from developing nations often emigrate, or remain in the industrialized nations where they may have received some education and training, instead of applying their skills at home – where the need may often be the greatest but prospects for present-day opportunities the worst. This 'brain drain' actively depletes some of the developing nations' human resources, and it is being exacerbated as the populations of wealthy countries get older, more people retire, and attractive employment opportunities arise there.

Wide as it is, therefore, the current gap is likely to grow even wider – perhaps becoming an unbridgeable chasm – as the industrialized nations continue to master the tools of science and invention, vastly outspend the developing nations in research and development, and even divert some of the developing nations' most precious human resources for their own use. [See Boxes 3 and 4 for descriptions of the current disparities in population and Gross Domestic Product (GDP) per-capita across nations, as well as population projections for 2015.]

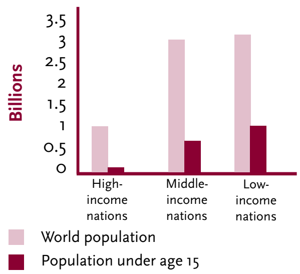
The high-income nations devote a significantly greater share of their national resources to science and technology, as reflected in expenditures for research and development. (See Box 5 for comparative data on national research spending as a percent of GDP.) While the high-income nations average 3,281 scientists and engineers per million population, the middle-income nations average 788. (See Box 6.) While patents granted to residents of high-income nations average about 346 per million population, the middle-income nations average 10. (See Box 7.) Moreover, the quality of developing-nation scientists' local training, not to mention the material resources at their disposal, is not on a par with what their industrialized-nation colleagues typically enjoy.

BOX 3 World population and GDP per-capita (2001)



Source: United Nations Development Programme, *Human Development Report 2003: Millennium Development Goals: A Compact Among Nations to End Human Poverty* (New York, N.Y.: United Nations, 2003). See: www.undp.org/hdr2003/

BOX 4 Projected world population and under age 15 in 2015



Source: same as box 3

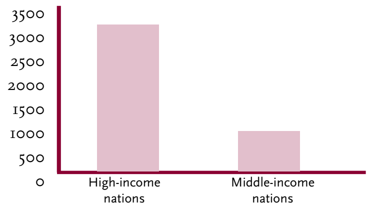
BOX 5 National research and development expenditures as a percent of Gross Domestic Product

Sweden	3.70	Brazil	0.91
Japan	3.01	Spain	0.89
United States	2.63	Poland	0.75
Republic of Korea	2.55	China	0.69
Germany	2.38	SouthAfrica	0.69
France	2.17	Hungary	0.68
Taiwan-China	1.97	Chile	0.63
Netherlands	1.95	Turkey	0.49
United Kingdom	1.87	Mexico	0.34
Singapore	1.47	Malaysia	0.22
India	1.20	Ecuador	0.08
Italy	1.04		
Russian Federation	1.06		

Sources: U.S. National Science Board, *Science and Engineering Indicators 2002*, (Arlington, VA: National Science Foundation, 2002), Text Table 4-13, pg. 4-47;and data for India are based on United Nations Development Programme, *Human Development Report 2003: Millennium Development Goals: A Compact Among Nations to End Human Poverty*.(New York, N.Y.: United Nations, 2003)

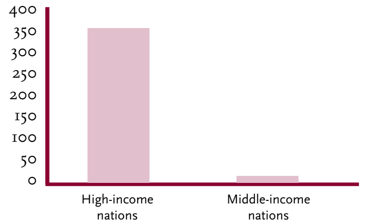
Note: Research and development (R&D) includes all expenditures for R&D performed by all R&D sectors within each nation. As the figures in this table are based on the latest available data on R&D and GDP during 1996-1999, the R&D/GDP percentage for any country listed here may have since changed.

BOX 6 Scientists and engineers in research and development (per million people)



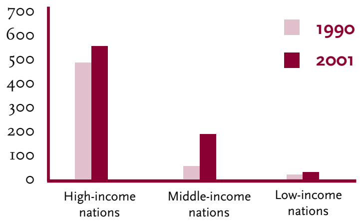
Source: United Nations Development Programme, *Human Development Report 2003: Millennium Development Goals: A Compact Among Nations to End Human Poverty* (New York, N.Y.: United Nations, 2003). See: www.undp.org/hdr2003/

BOX 7 Patents granted to residents (per million population, 1999)



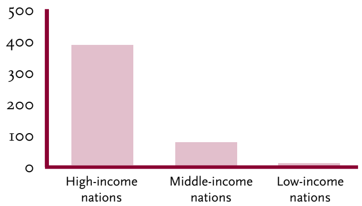
Source: same as box 6

BOX 8 Telephone mainlines (per 1,000 persons)



Source: Same as box 6

BOX 9 Internet users (per 1,000 people, 2001)



Source: Same as box 6

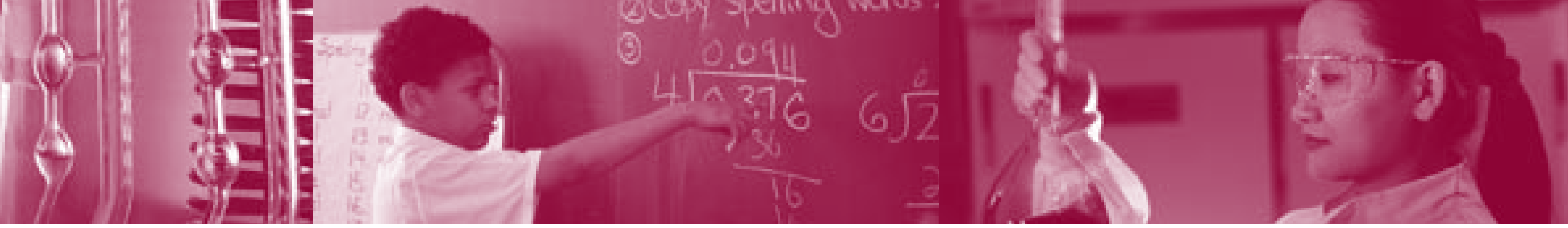
Such comparisons do not bode well for the ability of developing nations to participate in the new age of science and technology, so as to be more than mere consumers of the technological exports of the industrialized nations. The cultivation and deployment of human capital – building and maintaining the infrastructures that assure a nation's education, skills, and connectedness with the rest of the world – will be key to the ability of developing nations not only to improve their situation but to contribute to the welfare of everyone else. Surely the 80 percent of humanity living in those countries should have a greater input into the creation of new knowledge, not only for the right to shape their own destinies, but for the insight and talent that they can bring to the rest of the world.

The figures are troubling. Social and economic indicators in developing nations have not improved in the last decade, and many are getting worse. Today, the number of telephone lines per 1,000 persons stands at 592 in the high-income nations and at 152 and 30 in the middle-income and low-income nations, respectively. (See Box 8.) The number of personal computers per 1,000 persons is 430 for the high-income nations, 35 for those of middle income, and 6 for the low income. The high-income nations account for 15 percent of the world's population and 91 percent of its Internet connections. (See Box 9.)[4]

The future does not look any more promising. The industrialized nations are pulling farther in front of many of the developing nations in the preparation of the next generation of talent. In the late 1990s, tertiary-school enrollments in the low-, middle-, and high-income countries stood at 5, 15, and 58 percent, respectively, of the eligible populations.[5] And such quantitative indicators do not take into account the enormous differentials in quality of education, especially at the primary and secondary levels, between countries at either end of the spectrum.

Furthermore, societies continue to discriminate against women, who constitute half of the world's population but in many countries receive only one-tenth of the income and own less than one percent of the property. Women constitute about three-fifths of the world's illiterate, and in many regions receive less food, education, and health care than do men. In addition, certain cultural practices adversely affect the well-being of girls and women. Bad as it is, the situation is worsening in some ways – over the past 20 years, the number of rural women living in poverty has almost doubled.

With regard to cultivating S&T resources in particular, girls are discouraged from pursuing careers in science and technology, and the world thereby loses the potentially enormous contributions of most of its women. Even those few who overcome these obstacles face difficult career choices that require special attention. Furthermore, many ethnic, religious, and other minorities also face discrimination and are unable to develop to their full potential or to make their best contributions to society. This too will



require explicit attention in the design of any national program that seeks to promote S&T capacity building.

On the whole, an unprecedented large number of young people – many of whom would be quite capable of acquiring scientific and technological competence if given the opportunity – are coming of age within the developing nations without adequate opportunities for intellectual development or economic participation. To prevent the economic disparity among nations from continuing to increase, with worrisome social and political consequences, the talents of many of these young men and women should be channeled into productive participation in the global scientific/technological/industrial enterprise.

But while wealthy nations have come to understand that the most precious resource of a country is its human capital, given the knowledge that people may generate and their ability to use it, this is often not the case in less-developed nations where the urgency to overcome social malaise in the here-and-now leads to insufficient emphasis on longer-term needs. It is against this backdrop that we must address the role of science and technology, acting in a concerted and decisive fashion to apply them to meet head-on the challenge of poverty in our interconnected world.

1.3 Local S&T capacity is essential for using and contributing to the world's valuable store of knowledge

Changes will not occur spontaneously. The political, social, cultural, legal, and religious characteristics of a society can either help or hinder advances of the kind implied in the preceding sections, but even under the best of local circumstances, mere 'trickle-down' from the wealthy nations will not suffice. Leaving all of the scientific and technological breakthroughs to the highly industrialized nations and expecting the rest of the world to benefit from the results is an illusory and unproductive policy. The tools involved in such breakthroughs are often very sophisticated and their use requires a great deal of knowledge at the local level, as well as an ability to adapt and extend them to meet local needs. Moreover, collaboration among industrialized and developing nations is needed to address many global issues such as biodiversity loss and climate change.

Most technological challenges require interdisciplinary approaches involving science, engineering, economics, sociology, and public policy. Likewise, engineers increasingly need to think in terms of systems engineering – not only to improve the utilization of resources but because solutions in one area tend to create problems in others. Traffic problems, urban growth, industrial processes, and environmental protection, for example, are all areas that require this combination of problem-solving skills and a systems way of thinking, coupled with interdisciplinary teams and approaches.

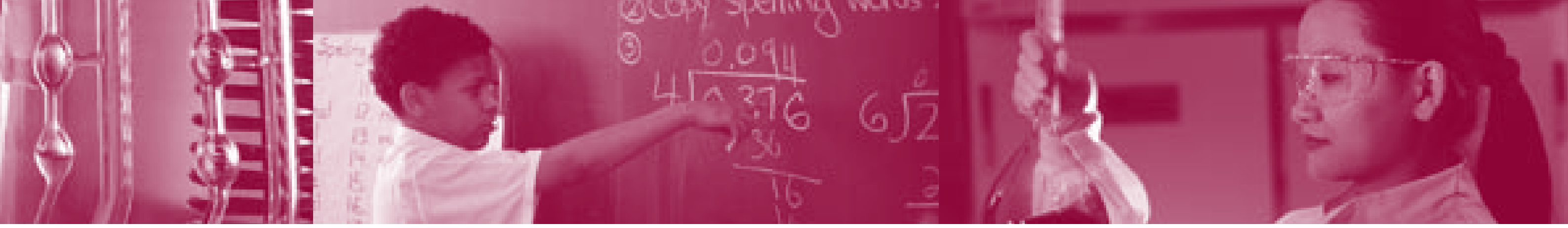
In working with less-developed countries to forge advancements that could bring about a more equitable balance of the wealth of nations, it is important that the highly industrialized nations provide infusions of capital and know-how to help people in the developing nations acquire, understand, and effectively apply these scientific and technological tools. The S&T-proficient countries – such as Brazil, Chile, China, India, Mexico and South Africa – can also fill a particularly useful niche in this regard. They can utilize some of the lessons learned from their own evolution, for instance, to help train young scientists, engineers, and medical professionals of S&T-lagging countries in critical fields.

Science and technology can play important roles in assuring developing nations' transitions to *sustainable* development – whereby human well-being is enhanced, the environment and natural-resource base are preserved and maintained for future generations, and consumption patterns support the goals of health and prosperity over the long term. Recommendations on these issues will prove more acceptable if backed by the advice of the international S&T communities, and of other thoughtful professionals, than if they result only from the interplay of political and power relations between nation-states.

Thus members of S&T communities – and in particular the academies of sciences, engineering, and medicine of many countries – should expand their contributions. While recognizing the deficiencies of some academies, by and large the membership of academies is drawn from the most eminent and influential persons in the national universities and the professional societies. They can help galvanize these institutions, working to establish high standards of quality in all S&T enterprises, to provide independent expert advice for helping to assure wise decisionmaking, and to build collective mechanisms for building understanding and meeting global, regional, and local challenges.

Such an expansion of the goals of academies is already under way. For example, as promised in their May 2000 statement on the role of science and technology in a transition to sustainability.[6] The world's scientific academies have committed themselves to applying the resources at their disposal along three main avenues to help developing nations achieve sustainable development:

- *Promoting the use of existing knowledge more widely and effectively* by improving education, strengthening worldwide S&T capacity, and building a global information network.
- *Generating new knowledge and beneficial technologies* by sustaining long-term basic research and linking it to societal goals; coupling global, national, and local institutions into effective research systems; linking academia, government, and the private sector in collaborative research partnerships; and integrating disciplinary knowledge into interdisciplinary, locally focused, problem-driven research and application efforts.



- *Applying the values of the practitioners of science and technology – openness, community, quality, and respect for evidence* – through involvement in the broad interactive processes of establishing societal priorities, analyzing the implications of policy directions, and fostering public understanding and the political will to ensure steady progress toward the realization of those priorities.

Science and technology, of course, do not automatically produce unmitigated good. Integral to the promotion of worldwide S&T capacity is the need to take potential ethical issues into serious account, as well as to assess the risks and dangers created by the greater ease with which modern capabilities can be misused.

Science and the practitioners of science should be constantly engaged in a dialogue with society at large. Not only will this benefit the decisions of society by bringing to bear the outlook and knowledge of scientists in the decisionmaking process, it will also help science to recognize the nonscientific aspects of decisions that affect scientific research and the deployment of its products. Through this dialogue of science and society, society will gain a scientific outlook while science will gain a new social contract.

So many obvious benefits are offered by the activities of scientific and technological research and development that they will continue to move forward, even if slowly or spottily, regardless of the relative disadvantage of some nations or the reservations on the part of some cultures. But we can do far better by working together to lower barriers and ease the minds of doubters – or at least achieve viable compromises. The challenges we face, therefore, concern our ability to help guide and quicken the ways in which development might proceed so as to serve the positive goals of as many countries and regions as possible.

A fundamental reason for global cooperation is this: the world is undergoing a transformation so profound that its contours can only be dimly perceived and the momentous consequences barely imagined. We are all passengers on the same ship, facing major challenges together as we sail into the unknown, and insights from all of our cultures and peoples are essential.

Can global cooperation be fostered in this time of unfettered competition? Can we find the means of reaching those at risk of being marginalized or left behind and seek out ways to assist their participation in the extraordinary S&T enterprise of the 21st century? That will depend on our collective ability to modify some aspects of current trends in order to help move the likely outcomes from business-as-usual extrapolations to more desirable outcomes. Systematic actions should occur throughout the world. In many countries, reforms are needed across the board in most local institutions. But that is beyond the scope of this report, which focuses on the institutions of science and research per se. We fully recognize, however, that the

enabling framework – the education and training system, political will and public support, for example – are all important parts of the equation.

We also recognize that some local institutions may place obstacles in the path of needed S&T reforms. Some of these obstacles result from misperceptions – that science and technology will be expensive propositions or that basic science is a luxury that poorer countries cannot afford. Some obstacles are created by fear of the potentially disruptive consequences of free-ranging inquiry and expression, which can threaten (or appear to threaten) the religious foundations, as well as the secular ideologies of various societies. Other barriers result from science and technology being seen as synonymous with types of modernization that some local leaders believe will disrupt the continuity and integrity of well-established cultural patterns. Still others reflect fear of the economic and social costs of technological transformations in production.

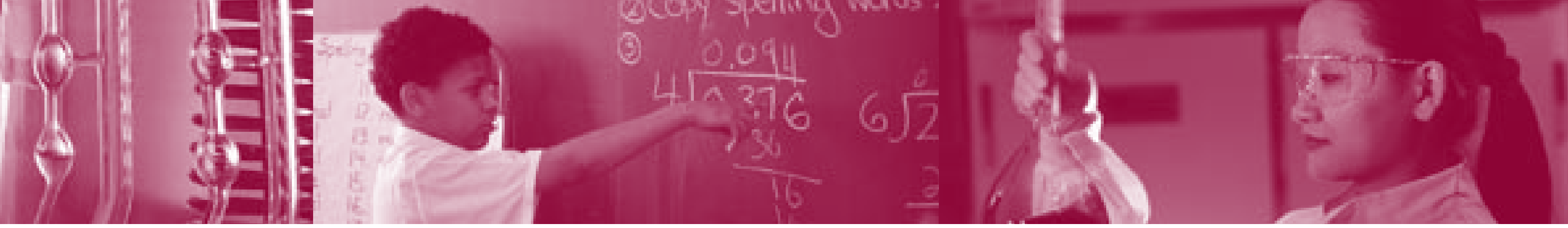
Another set of concerns focuses on the potentially hazardous aspects of new technologies and the continued use of old technologies with harmful side effects. Whether we think in terms of massively destructive weapons, environmental degradation, biological and chemical threats, or other challenges, it is obvious that we can now create highly dangerous materials and products far more easily than we can limit and control their use. In this sense, science and technology – broadly defined – have presented us with increasingly deep ethical, political, and human dilemmas whose resolution will test the capacities of all societies.

It is essential that the S&T communities, including all those favoring the expansion of S&T capacity building, engage the reluctant parties, recognize the merits of concerns where they are justified, and focus on how science and technology can be of fundamental importance in helping to allay many other concerns. With a strong political will, less bureaucratized administration, a change in the mindset of the S&T community itself, and committed resources, the desired goals could well be achievable.

1.4 Universities have an essential role to play in building S&T capacities

In most countries, the major focus of scientific research is located within the organizational framework of universities. Research performed within universities has an added value because of its beneficial effects in raising the level of education provided to the professional elites who are trained there.

Yet in many of the developing nations, higher-education systems have been subject to enormous social and political pressures to massively increase their enrollments. Some of these changes have caused significant reductions in quality and vitiated the ability of universities to play the role that



is expected of them. But other institutions have succeeded in enormously expanding enrollments and weathering political pressures while maintaining research programs on par with the best in the world.

The university in developing counties has a special function as a locus for the modernizing forces of society, for the promotion of the 'values' of science, and for mediating between the political and industrial spheres of a nation's life. The university's research facilities in particular must orchestrate the brainpower of the faculty, take responsibility for training new generations of talent, and participate in the transformation of the nation's S&T base. Regrettably, the current structures of higher-education systems in many countries are inadequate to meet the challenges of the 21st century. Wide-ranging reforms are needed, as the university system should be the centerpiece of any human-resource development strategy for S&T capacity.

The reform of higher-education systems – in the industrialized S&T-advanced countries as well as in the developing nations – has been the topic of several studies and reports.[7] Although a fuller treatment of such a complex topic is beyond the scope of this report, the Study Panel points out that special attention to university governance, balancing autonomy with national purpose and ensuring institutional pluralism in the education and training system, will all be necessary. More specifically, university reforms should encompass the following actions:

- Modify academic and governance structures that create barriers for change and for the conduct of interdisciplinary and transdisciplinary research. This reform should include promotion of an interaction of the physical, biological, and earth scientists with academics in the humanities and social sciences.
- Strengthen merit-based academic policies and procedures that allow young brilliant academics to climb the academic ladder and gain intellectual independence.
- Promote the regular evaluation of university departments, institutes, and faculties by external reviewers, including international experts.
- Establish transparent and rigorous systems of institutional and program accreditation at the national and international levels. This is especially crucial for post-graduate level programs.
- Emphasize systems of accountability for public investments in higher education.

In particular, the promotion of special world-class research programs in universities will be essential for meeting the challenge of building capacity for science and technology. Such research programs should have a great degree of autonomy and should develop and exert their influence in the short term, even while the needed reforms of the entire system proceed over a longer-term horizon.

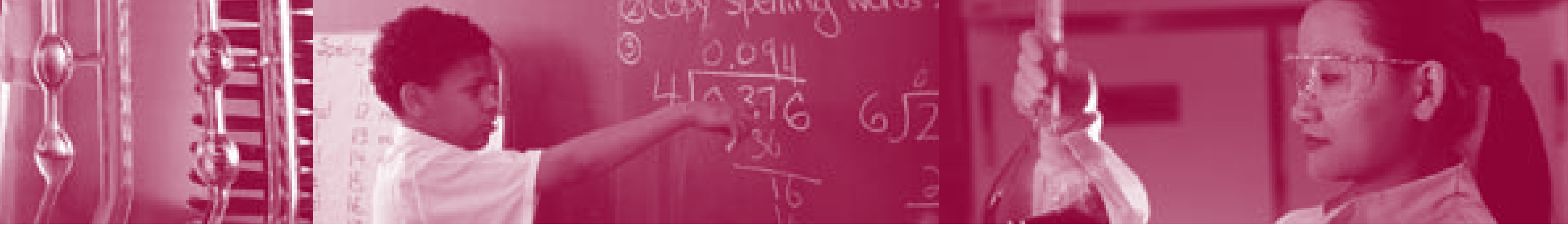
1.5 The culture and values of science are critical for building a global community

In most nations and in most international forums, there is increased openness and debate as scientific exchange flourishes more than ever. Indeed, science has developed a set of complex experimental methods and symbolic languages, the broad acceptance of which has allowed it to cross the ordinary linguistic barriers that so often separate people from one another. In this sense, science has achieved more universality than any other distinctive mode of knowledge. A new finding, theory, proof, conjecture, set of computations, or formula can be 'read' and evaluated by individuals and groups across very different cultures. This is essentially because the receiving parties, despite their widely varying local cultures, share with the originator certain ways of observing, analyzing, describing, and interpreting natural phenomena.

As a consequence, there is a considerable 'world community' of scientists who know each other's work, frequently collaborate on projects, and build on one another's discoveries. Not only does this process add to the vigor of scientific advancement, it also creates many personal and professional international friendships that aid mutual understanding – strands of connectedness across cultures that represent an especially important asset at this moment in history.

Two important assumptions that scientists share are also critical to the process of international collaboration and the building of a global community. First, there is the paramount goal of seeking truth without being constrained by ideologies or their possible forms of interference. Essentially, scientists trust that their work, if done with care and integrity, will eventually lead to conclusions that contribute to a deeper understanding of nature. In that spirit, the 'openness' of science is profoundly important. Given the fact that some scientific findings, if they are held in confidence, can lead to substantial financial rewards – or that the findings can be very useful, if kept secret, to national security – it is significant that most of the world's universities are committed to the prompt communication and publication of research findings. In this way, new ideas are made widely available in order to be studied, critiqued, and tested by others. This moral, ethical, and professional commitment to openness is what upholds the integrity of the scientific enterprise.

And second, a dynamic such as the one just described – involving the swift exchange and intense scrutiny of new findings – creates considerable energy that, in effect, takes on a life of its own. The rapid international circulation of new discoveries or theories accelerates the process of generating new ideas, which in turn leads to additional discoveries. Indeed, looking back over the past half-century, it seems clear that the major investments



made in basic and applied research after World War II have had a cumulative and compounding effect, the benefits of which we have begun to reap. The rate of significant observations and discoveries, across all scientific fields, has quickened noticeably in the past 10 to 15 years, and the decades immediately ahead could potentially become one of the most significant eras in the history of scientific advancement.

There is a central core of universal values – rationality, creativity, the search for truth, and an adherence to codes of honorable behavior – that any truly modern society should possess, and these are values that science promotes. They are corollaries of independence, of dissent against received wisdom that require the ability to challenge the established order – the right to be heard however outlandish the assertion – subject only to the test of rigorous method.

Without independence of inquiry, there can be no true scientific research. The safeguards that independence requires are obvious: free inquiry, free thought, free speech, tolerance, and the willingness to arbitrate disputes on the basis of evidence. These are societal values worth defending, not just to promote the pursuit of science but to yield a more open-minded society that adapts to change and embraces the new.

Thus science is not only itself a culture of global dimensions, it induces a cultural current that strongly and positively affects societies in which it flourishes – including those that at first were wracked by poverty and hunger, riven by civil strife, and embedded in fiscal crisis. Science brings imagination and vision to bear not only on theoretical speculations but on practical problems and critical decisions, allowing people to analyze present (and future) situations, make sounder choices, and invest their resources more wisely. The culture of science and the open, honest values it engenders are enormously important above and beyond the material benefits that they help produce for human welfare.

1.6 Investments in science and technology are increasingly important for economic growth

While it is not possible to demonstrate a direct causation between the rates of investment in research and development[8] and outcomes in terms of increased GDP, it is true that a growing level of investment in research and development is generally correlated with improved GDP-growth outcomes. But how much should countries invest in research and development, and in what kind, to ensure for their citizens the material benefits that science and technology can bring? Alternatively put, given the many competing claims on scarce public resources, what would be an 'appropriate' level of investment for countries at different levels of economic development?[9]

When national activities in research and development are taken as a

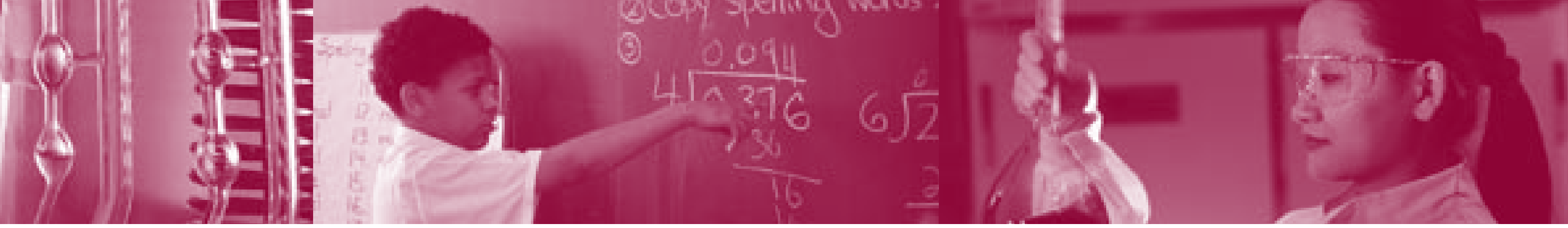
whole, it is seen that the wealthy industrialized nations – Australia, Canada, Japan, South Korea, the United States, and northern and western Europe – all spend between 1.5 percent and 3.8 percent of their GDP on research and development, whereas the countries of eastern and southern Europe tend to have R&D/GDP ratios of less than 1.5 percent.10 It is clear that countries making heavy investment in research and development also have strong high-technology industrial and service sectors. And it is noteworthy that the private sector finances most of the research in these countries.[11]

By contrast, the lower the per capita income of a country, the greater tends to be the role of government in funding research and development. With severe competitive pressures for limited government budgets, the result is modest overall spending for research and development and relatively low R&D/GDP ratios. While developing nations with large economies have approached the lower-end R&D/GDP ratios of OECD countries (for example, India allocates 1.2 percent; Brazil, 0.91 percent; and China, 0.69 percent), most developing nations devote less than 0.5 percent of their GDP to research and development.[12]

This situation makes it essential that efforts to improve the overall capacity in science and technology be accompanied by increased public spending on research and development, with initial investments normally occurring at the development end of the spectrum and supporting more fundamental research as an economy grows. National governments in developing nations should increase their spending considerably, certainly above 1 percent of GDP and preferably closer to 1.5 percent, if there is to be any hope of not falling farther behind the industrialized states.

Precedents do exist. Successful economies, such as those of the 'East Asian Tigers,' have achieved much by focusing on education and investing in research and development. The figures from South Korea (2.55 percent), Taiwan-China (1.97 percent), and Singapore (1.47 percent), and the considerable material benefits accruing to the people of those countries, are renowned stories of success.[13]

A strong S&T capacity can thus translate into accelerated industrial and economic development in what can be termed a positive spiral of mutual reinforcement. However, the Study Panel is also convinced that simply limiting actions in science and technology to the utilitarian needs of the 'productive sector' will limit the effectiveness of the effort in this very rapidly changing environment, especially in areas where scientific and technological knowledge are likely to play an exponentially increasing role.



1.7 Building capacity in agriculture, engineering, health, and the social sciences is essential for national development

Science and technology, as described in this report, encompass the full range of fields and disciplines, including aeronautics and astronautics; agricultural sciences; anthropology; biology; brain and cognitive sciences; chemical engineering; chemistry; civil and environmental engineering; earth, atmospheric, and planetary sciences; economics; electrical engineering and computer science; systems engineering; health sciences and technology; materials science and engineering; mathematics; mechanical engineering; nuclear engineering; physics; political science; psychology; and sociology.

The areas of agriculture, engineering, and health, however, loom large in addressing the challenges of developing nations. The study of agriculture, engineering, and health is closely related not just to research but to practice. Therefore the nature of the training enterprise and the types of research institutes, such as teaching hospitals, agricultural research centers, or S&T parks located near or linked to university complexes, are somewhat different from the more standardized image of scientific laboratories and academic departments that this report may seem to imply. Yet these differences can be overdrawn. Our primary focus is on the development, mastery, and adaptation of knowledge – something shared among the sciences and engineering and medicine. The distinction lies simply in the *type* of knowledge that is particularly valued.

Although the social sciences differ from the physical, biological, and mathematical sciences in their focus on human behavior, the development of social-science capacity should be regarded as no less important. The role of well-trained and insightful economists, sociologists, anthropologists, political scientists, public-administrators, and other social-science professionals is specially important in providing policy analyses, developing the S&T culture, building institutions, and maintaining the public-private interface for S&T promotion.

In the developing world especially, the need for problem-solvers working together in an interdisciplinary and systems-level fashion is critical. Technical experts who labor essentially alone are necessary there, but not sufficient.

1.8 Our recommendations represent universal needs for inventing a better future

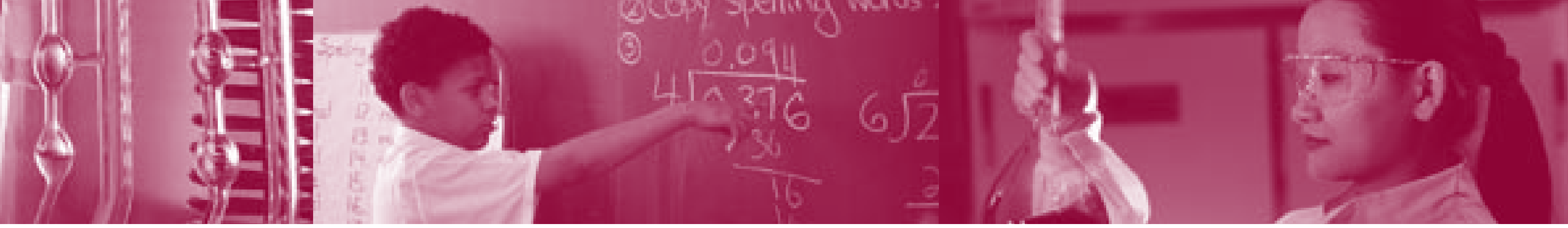
There is much that individual countries can do to change the course of events so that the benefits of science and technology flow more equitably to all members of the human family. The outcomes that should be sought are the strengthening of S&T capacity everywhere and the stemming of the growing divide between the industrialized and developing nations. A stronger S&T capacity in the developing nations – for research and practice alike – is not a luxury but an absolute necessity if they are to participate as full partners in the world's fast-forming knowledge-based economy.

The stunning example of South Korea in recent decades shows what can be accomplished by a nation devoted to building up its S&T capacity. But the prescriptions that worked in the past will not necessarily be those that work in the future. In addition, each country's circumstances are different, so that the areas they need to focus on and the issues they have to address will vary.

However, as a result of its extended inquiries the Study Panel has been able to make numerous recommendations that should have wide applicability. Some are oft-repeated items where, regrettably, actions and achievements have not matched the rhetoric. Others are relatively novel and deserve broad distribution and serious consideration. For the reader's convenience, these topics have been grouped into five clusters, respectively addressed in each of the five succeeding chapters:

- *Science, technology, and society:* Major issues of policy for promoting science and technology and their use for policymaking.
- *Human resources:* The attraction, development, and retention of talent in the fields of science and technology.
- *Institutions:* Centers of excellence are needed for science and technology to flourish. Virtual networks of excellence (VNE), linking professionals from different locations working on similar problems through the power of new information and communications technology, can multiply the potential effectiveness of individual centers, as can regional cooperation between countries.
- *Defining the public-private interface:* The private (and the literally 'productive') sector is now the primary global force in research and development for science and technology, and clear distinctions between public goods and proprietary interests help in the establishment of true public-private partnerships.
- *Financing:* To complement national efforts, creative new mechanisms are needed to ensure adequate funding for S&T capacity building.

Many of the recommendations have applicability to both developing and industrialized nations. For example, those pertaining to an insistence on



merit reviews, the direction of young talent toward science and technology, involvement of the science and technology communities in public issues, interaction of scientists and technologists with the productive sectors, clarification of the relationship between the public and private domains and protection of public-goods research, and support for universities' research functions are universally applicable measures that can benefit the industrialized and developing nations alike.

Because capacity building in science and technology is likely to be demanding and far-reaching – and, ultimately, tailored to each country's particular situation – it will require the involvement of all pertinent social actors for its implementation. This is especially needed in pursuing a comprehensive approach: one that recognizes the recommendations as an integrated package – a whole that is considerably more than the sum of its parts.

These social actors include:

- S&T-proficient and S&T-developing countries;
- S&T-lagging countries;
- S&T-advanced countries;
- United Nations agencies and regional intergovernmental organizations;
- Educational, training, and research institutions;
- Academies of sciences, engineering and medicine;
- National, regional, and international S&T organizations;
- International development-assistance organizations;
- Foundations;
- Local, national, and international private sectors (for-profit entities);
- Nongovernmental organizations;
- The media

A program of action for global capacity building in science and technology would not necessarily be seen by most of these actors as topmost on their agendas, much less as beckoning them to work together to pursue it. The community of scientists – national, regional, and international – must therefore take the lead in reaching out to other actors, especially the media and decisionmakers, in order to forge a coalition that reflects a clear appreciation of each of the five clusters of recommendations and their 'greater than the whole' interconnectedness.

2. Science, technology, and society

Nearly all nations now recognize that science and technology are of vital importance to their development. Yet science and technology (S&T) cannot just be imported as commodities from foreign producers. For a country to enjoy the full benefit of science and technology, they must be deemed critical to the effort to achieve economic well-being and social justice, integrated into the societal decisionmaking structure, and systematically supported by policies that nurture the nation's capacities and indigenous talent. Such interactions require the following:

- *Policy for S&T:* A national commitment, by the public and private sectors alike, to promote science and technology;
- *S&T for policy:* A mechanism for providing S&T inputs into decision-making;
- *Dissemination of knowledge:* Procedures for broad public participation in critical issues, especially regarding their S&T aspects.

2.1 National S&T strategies identify priorities for addressing critical needs

Many of the recommendations in Chapters 3 through 6 that follow can be seen as parts of national policies for the promotion of science and technology. Recommendations on human-resource development, institution-building for science and technology, establishing new modes of cooperation for the private and public domains, and the generation of new funding mechanisms will all require support from a nation's leaders, both in and out of government. There is a need to provide a coherent framework for these actions. In each nation, a national S&T strategy should be developed by the government in consultation with scientific, engineering, and medical academies; the professional societies of the country; and its industrial sector. The strategy should benefit from the experiences of other countries, and it should spell out the government's commitments to funding; standards of excellence; openness and dissemination of knowledge; regional consortia and networks; private-public interactions; and partnerships with others – locally, regionally, and globally. (See Box 10 for a description of an ambitious strategy in China to upgrade its S&T enterprise.)

The practice of science in particular cannot be undertaken without a profound adherence to what has been called the values of science – a commitment to truth and honor, a certain constructive dissent among scientists, and the arbitration of disputes through rigorous methods.

BOX 10 Pilot Project of the Knowledge Innovation Program (PPKIP), Chinese Academy of Sciences

The PPKIP is an ambitious 12-year project (1998-2010) led by the Chinese Academy of Sciences (CAS) to reform and revitalize China's science and technology infrastructure.

By 2005, the Chinese Academy of Science plans to have:

- significantly enhanced scientific output in fundamental research in strategic areas;
- increased the numbers of scientific research personnel in multidisciplinary and frontier areas;
- created new joint laboratories with universities;
- established long-term cooperative relationships with distinguished foreign universities, research institutions, and companies;
- transformed 15-20 academy-affiliated research institutions into for-profit corporate entities;
- built high-tech incubators jointly with local governments;
- introduced venture-capital mechanisms through creation of CAS-managed venture-capital funds; and
- sold shares of Chinese Academy's companies in stock markets, both at home and abroad, thus attracting capital for the rapid development of high-tech enterprises.

english.cas.ac.cn

BOX

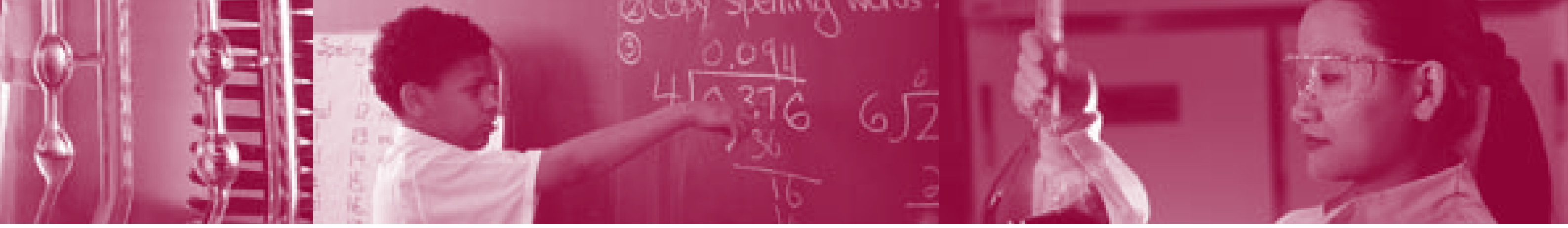
But science is seldom left only to the scientists. Research-agenda priorities derive not just from the wishes of scientists or their interest in certain problems but also from factors such as national needs, the availability of funding, access to tools of research, and the commercial prospects for deploying the resulting technologies. What gets studied, in effect, is often decided by nonscientists. Some governments' restrictions on certain biological research areas, for example, or a nation's response to the unavailability of industrial funding for specific (often long-term) areas of research and development with limited commercial payback, are instances of how governments deploy scientific capacity in research in response to societal goals.

The application of science for utilitarian purposes, however, usually depends on earlier basic research that was driven by scientists' intellectual curiosity. Allowing some space to satisfy this drive, therefore, should be an element of any program to increase capacity building in S&T and maintain its productivity over the long term.

The exact balance between basic, strategic, applied, and adaptive research will vary from country to country, as will the domains in which the resources and talents should be deployed. However, it is becoming increasingly evident that old classifications between basic and applied, as well as the boundaries between traditional disciplines, are being overtaken by events. New S&T research increasingly involves multiple disciplines and often requires conceptual and applied skills alike.

Recommendations

- ▶ Every nation should develop an S&T strategy that specifies the national priorities for research and development and spells out national funding commitments.
- ▶ National governments should develop national strategies for science and technology in full consultation with the country's science, engineering, and medical academies, its professional societies, and the industrial sector.
- ▶ The national strategies should include support for basic science and recognize the need for high-level training to develop, as much as possible, national competence in selected frontier areas of science and technology that are most suitable for sustainable economic development and social well-being.
- ▶ National funding commitments for science and technology should rise to at least 1 percent – preferably 1.5 percent – of Gross Domestic Product for each developing nation, and should be disbursed using a merit-based approach.



2.2 Independent scientific advice improves decision-making for public policies

The effectiveness of government programs can be greatly increased if inputs and independent review are provided by scientific, engineering, and health experts – honest brokers who bridge the gap between what is technically possible and politically achievable in areas such as agriculture, education, energy, environment, and health. For example, many international deliberations, running the gamut from intellectual property rights to environmental and health regulations, require governments to fully understand the S&T premises that underlie the decisions they are negotiating. Each country therefore needs to create suitable mechanisms for providing impartial scientific and technological advice to government policymakers. Informed and reliable counsel could come from specially appointed committees of experts, standing multidisciplinary advisory bodies, independent institutions such as merit-based academies of science, engineering, or medicine, or from professional societies. (Box 11 offers an example of how S&T capacity is needed to inform government policies on emerging health issues.)

BOX 11 World Health Organization promotes national capacity to confront new diseases

The need for local biomedical expertise in all nations, complemented by other health professionals worldwide, has been demonstrated by the emergence of severe acute respiratory syndrome (SARS), an illness first reported in 2003 in Asia, North America, and Europe. The World Health Organization (WHO) is coordinating an international investigation with the assistance of the Global Outbreak Alert and Response Network – a collaboration of existing institutions and networks that pool human and technical resources for rapid identification, confirmation, and response with regard to disease outbreaks of global importance. The Network keeps the international health community constantly alerted to the threat of new outbreaks and provides appropriate technical assistance to affected states by strengthening local infrastructure and capacity to reduce illness and prevent disease spread. Since its inception, the Network has addressed health concerns in Afghanistan, Bangladesh, Burkina Faso, China, Côte d'Ivoire, Egypt, Ethiopia, Gabon, Kosovo, India, Madagascar, Pakistan, Republic of the Congo, Saudi Arabia, Senegal, Sierra Leone, Sudan, Uganda, Yemen, and Zanzibar.

www.who.int/en/

Recommendations

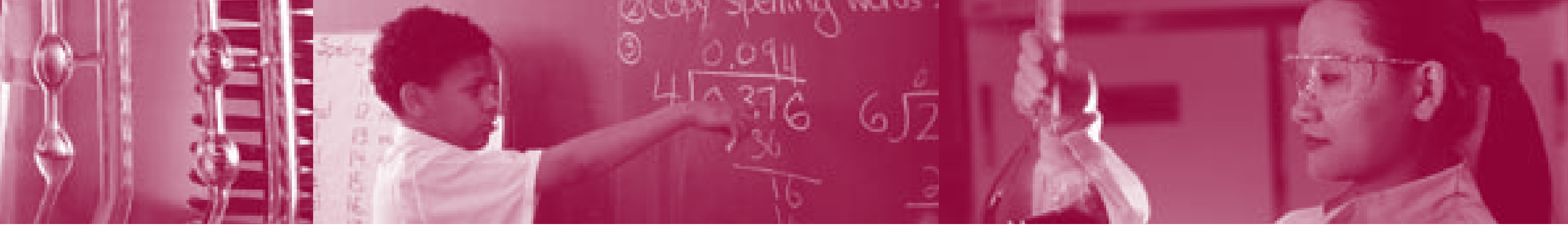
- Each national government should establish trusted indigenous mechanisms for obtaining advice on scientific and technological questions related to policies, programs, and international negotiations.
- Each nation involved in the development, production, or use of new technologies, such as those deriving from biotechnology, should have the means to assess and manage their benefits and risks. Governments should therefore ensure that indigenous S&T capacities are in place (with international inputs when necessary) not only for effective adoption of a new technology, but also for help in implementing public-health, human-safety, and environmental guidelines or regulations that address potential side-effects of the new technology. The possibility of long-term effects should be kept in mind when setting up such systems, which must remain fully adaptable to rapid advances in scientific and engineering knowledge.
- The coordination of such efforts among nations to permit the sharing of experience and the standardization of some types of risk assessment is highly desirable.

2.3 The public requires dissemination of new knowledge for addressing critical issues

The world's communications networks have begun to give each individual scientist or technologist the means to help close the knowledge gap between industrialized and developing nations. Through the global system that the S&T community is creating on the Internet, local investigators can stay up to date on, and participate in, cutting-edge research. And because these indigenous professionals generally understand their nation's culture and can easily communicate with its people, they are uniquely placed to be disseminators of advanced knowledge and know-how to other critical local actors – greatly increasing the likelihood that the new technologies will be well adapted to that society's needs and cultures. Any nation without such a core of scientists and technologists can expect to fall farther and farther behind the rest of the world.

Countries at different stages of development will of course need different types of S&T expertise, and they may be expected to invest in science and technology at different rates. But even in the poorest nations, a substantial enrollment in higher education is essential, particularly in science and engineering courses. For that to happen, S&T practitioners should become sufficiently involved in education at all levels to help generate the human capital on which so much of development depends.

Beyond communicating among themselves, with policymakers and their students, the S&T community should regularly interact with the public. Many issues require public debate, and scientists and engineers should help inform this debate by engaging with the media. For its part, the media should consistently seek out the most reliable sources in order to present the issues accurately and effectively.



Recommendations

- ▶ With the help of the S&T communities, each national and state government should encourage innovation in disseminating the results of publicly or privately funded research and in turning them into new products and services that address national or local needs. Such efforts could include:
  - Consultative services, provided by national, state, or city research institutions, in areas such as agriculture, water and land management, housing, and health.
  - Cooperative partnerships between local (state, city) entities and research institutions for sharing up-to-date information of local relevance.
  - Empowerment, for periods of time, of social entrepreneurs for supplying products and services significantly below market prices to people in need.
  - 'Information kiosks,' either publicly funded or for-profit, to help distribute useful scientific information to the public. The information might consist of short publications prepared by scientific organizations, such as the recent ones being promoted by the Third World Academy of Sciences (TWAS), or reliable news obtained from the Internet.
- ▶ Each nation's media should assume major responsibility for educating the public in S&T-related issues.
- ▶ A wide array of communications technologies – print, television, radio, cellular telephone, World Wide Web, the Internet, among others – should be utilized in disseminating to the public the results and public policy implications of publicly or privately funded research that addresses national or local needs.
- ▶ The S&T community should seriously exercise its obligation to pay more attention to the media and participate more fully in public discussions and debates. In such interactions, practitioners should endeavor to explain technical issues in non-technical language.
- ▶ Regarding scientific or technical matters on which public-policy choices are to be made, the media should seek out the best S&T sources for their articles and programs. In a similar spirit, reporters and editors should not artificially generate controversy by seeking out minority positions that appear to highlight the adversarial aspects of S&T-related questions, particularly when the professional community has actually achieved broad consensus.
- ▶ Truly controversial questions should be presented to the public in terms of explaining the scientific and technological aspects of the dispute without bias or editorializing (except on clearly indicated opinion pages).

3. Expanding human resources

While leaders of nations issue numerous calls for curing the ills that face humanity and improving quality of life, little is said about the necessary human resources for turning these lofty goals into reality. Much is required of a nation's human resources, especially its science and technology (S&T) professionals:

- Creation, maintenance, and continual modernization of an education base, from primary school to university level, for training new generations of scientists and engineers, as well as others among the nation's future leaders;
- Generation of technological innovations;
- Capability to access and productively use new technologies;
- Full participation, as equal partners, in international initiatives designed to solve global problems.

If the world is to be changed for the better, national policies and international support must focus on a key set of prerequisites – the right people should be trained in sufficient numbers to do the job. Moreover, incentives should be provided, such as high-quality working conditions, to retain them in their home country.

Basically, the time has come to give first priority to national competencies for bringing about sustainable development in each country. In particular, serious progress is needed in four key areas of activity:

- Providing high-quality education at all levels, from elementary school to university to specialized training, with a focus on young scientists and engineers;
- Developing, attracting, and retaining the country's S&T talent (the 'brain-drain/brain-gain' issue);
- Building international networks;
- Creating digital S&T libraries.

Each of these four areas is discussed, together with appropriate recommendations, in the following sections. Excellent and engaging science education to attract future scientists and engineers is especially emphasized.

3.1 High-quality education and training are essential in all nations

Because so many of the urgent problems facing humanity today have potential solutions derived from science and technology, it is vital that science and technology become part of the mainstream of the education system. Courses providing the basis of S&T literacy and reasonable

familiarity with scientific and technological culture should be required at all levels and for all students, including the many who do not intend to specialize in science or engineering. A substantial increase in university-student enrollment in those areas should become a key strategy for the development of science and technology in the country.

This can only occur if S&T literacy and culture are imparted in ways that capture the interest and imagination of young learners. But education will not achieve that quality unless the number of teachers knowledgeable in science and technology – and the quality of *their* education is increased first. In most countries (industrialized and developing alike), there is a dire shortage of such teachers, and even if their formal training was first-rate they are usually unable to keep up with constantly evolving S&T developments. It is therefore difficult for them to provide up-to-date knowledge to their students or fruitfully apply the most recent teaching innovations.

The result is that students often become bored or discouraged; some who would specialize in science or engineering may shift to other fields, and the majority of students run the risk of becoming illiterate in these areas, or even phobic, for life. This perpetuates the vicious cycle of not having enough qualified scientists and engineers, qualified teachers, or 'S&T-qualified citizens' coming out of the education system.

Much more serious efforts are needed to remedy the situation. In that spirit, S&T-related academies and societies have been launching projects that pair active researchers with teachers in elementary, middle, and high schools in order to facilitate learning. (See Box 12 for a description of the science education program of the InterAcademy Panel.) Useful examples of scientific academies promoting new modes of science education – and of enthusiastic responses among students – are shown in the boxes on the French program La Main à la Pâte (Box 13) and the U.S. National Science Resources Center (Box 14).

Another set of activities that have successfully stimulated young-student interest in S&T are science olympiads – national and international contests for schoolchildren in mathematics and sciences such as biology, chemistry, and physics. Besides improving science visibility and teaching at all levels, these olympiads have been useful in many countries for discovering and cultivating young talents. (See Box 15.)

The private sector has also been getting involved, as companies see that it is in their interest to improve the S&T education of people in whose communities they operate; this makes for better community relations and a larger and more capable labor pool from which to draw. (See Box 16 for four examples of corporate support for science education.)

When students do decide to pursue careers in science and technology, they are more likely one day to reach the highest levels of their profession if they have been trained at the finest science and engineering research universities. These institutions offer sophisticated faculty that conduct world-

BOX 12 InterAcademy Panel's science education program

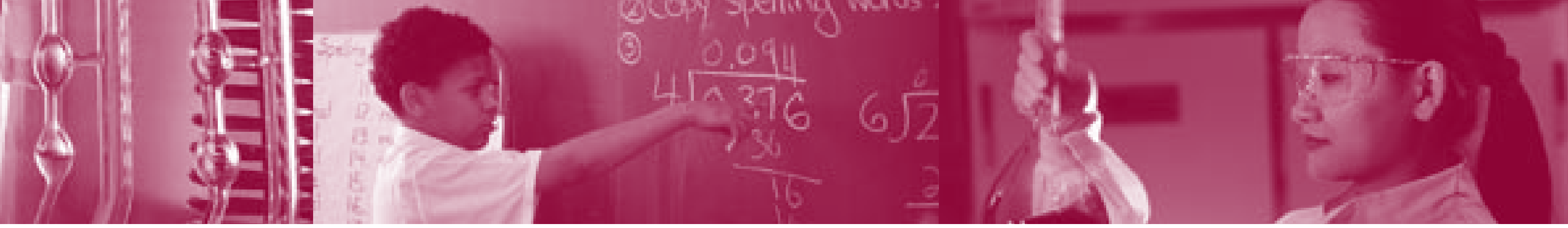
The InterAcademy Panel on International Issues (IAP), an association of over 90 national scientific academies, provides a forum for addressing issues of critical global importance and strengthening the public-service contributions of scientific academies worldwide. The IAP has become a significant force in global efforts to reform science education, sponsoring conferences and workshops throughout the world to advance best practices. Emphasizing the experiences of different countries, IAP events address such topics as science education for girls; the use of information and communications technology; curriculum development and teacher training; the use of culture-based stories and hands-on projects; the role of industrialized nations in improving science education in developing countries; and the creation of regional networks for improving science education. During 2002-2003, the IAP helped to organize science-education conferences in Malaysia, Egypt, Mexico, India, and China.

www.interacademies.net/iap

BOX 13 French Academy's *Opération La Main à la Pâte* (Learning in a 'hands-on' way)

Opération la Main à la Pâte was developed by French Nobel-laureate physicist Georges Charpak after seeing a novel science-education program in Chicago, Illinois, in which children from poor neighborhoods learned science through their own observations and experiments. Endorsed and promoted by the French Academy of Sciences, *La Main à la Pâte* helps children to participate in the discovery of natural objects and phenomena. Instead of directly answering students' questions about their environment, the teacher challenges them to form hypotheses, perform simple experiments, and communicate the results. The pedagogical principle here is that even when an experiment fails and the teacher ultimately provides the answer in the traditional way, children's personal engagement is often an enjoyable experience that brings science to life for them. The techniques of *La Main à la Pâte* programs have been introduced not only to schools in France, but also in Afghanistan, Morocco, Egypt, Chile, China, Brazil, Senegal, Hungary, Colombia, and Malaysia.

www.inrp.fr/lamap/



BOX 14 U.S. National Science Resources Center (NSRC)

The National Science Resource Center (NSRC) was formed in 1985 by the Smithsonian Institution and the U.S. National Academy of Science, National Academy of Engineering and Institute of Medicine to improve learning and teaching of sciences for students ages 5 to 18 throughout the country's school districts. The NSRC's 'science education reform model' is based on hands-on, inquiry-centered investigations; associated reading, reflection, discussion, analysis, and communication; the linkage of students' newly acquired concepts and skills to their everyday lives; and integration of science with other areas of study. The NSRC complements this effort with programs to improve teachers' skills, and it involves other players, such as practicing scientists and engineers, in the process. As a result of NSRC technical-assistance programs, 369 U.S. school districts are implementing this new vision for science teaching and learning. These school districts serve more than 6.8 million students in kindergarten through grade 8, or approximately 25 percent of the nation's schoolchildren. The NSRC model for science-education reform is being emulated in Sweden, Mexico, Canada, and elsewhere.

www.si.edu/nsrc

BOX 15 International Science Olympiads: Improving visibility, teaching and talent searching

Olympiads in mathematics and physical sciences are under way in some 85 countries, industrialized and developing alike, and they occur on regional and international scales as well. If properly structured, olympiads can serve as major instruments for promoting science to young students. They are vehicles for improvement of science teachers' skills, and they aid in the detection of young scientific talents. To achieve these three goals, the olympiads should be large-scale events in each country, at several grade levels and in three different stages at each level. The first test is very friendly to students and their teachers, with many winners and simple prizes. The second stage involves those who performed well in the first stage. Finally, a third stage determines the best talents, who then compete internationally and are awarded fellowships for further science training.

scientific.olympiads.ch/de/index.html

BOX 16 Corporate support for science education

AES Gener. Programa Amigos de la Ciencia (Friends of Science) is a Chilean educational project financially supported by AES Gener, the Chilean branch of a privately owned electric-power company. Since 1995, over 40,000 children from impoverished backgrounds have participated. During 90-minute workshops held in factory offices some 40 weeks a year, students are guided to learn by discovery through a carefully designed sequence of activities. In preceding summer sessions, teachers have been presented with exactly the same research problems later posed to their students. Through this program, children can acquire new abilities and learn concepts and fundamental principles of different scientific disciplines. They are more fully prepared to pursue scientific studies in their secondary education.

Dow Chemical Company. The aims of Dow's science-grants program are to improve math, science, and technology education; upgrade teacher training and development; and increase parental involvement. The company focuses on school districts and boards in Dow-factory communities rather than on individual schools, and on programs that promote systemic educational reform. The company also pursues projects with key strategic partners, such as one with the U.S. National Science Resources Center where Dow gave financial assistance to 42 school districts for the organization of science centers, dissemination of new science-curriculum materials, and teachers' professional development.

Hewlett-Packard Company. Hewlett-Packard reports that in 2001 alone it 'contributed more than $54 million in resources worldwide to advance the ability of students, teachers, community residents, and nonprofits to solve some of their most fundamental challenges.' The company's programs sponsored the attendance of five U.S. school-district teams ranging from kindergarten to grade- 8 from low-income, ethnically diverse communities at the National Science Resources Center Institutes; supported the Institute for Women and Technology's Virtual Development Centers; built 'digital villages' in two communities in Ghana and South Africa; and recognized some of the Asia Pacific region's most promising minds through Young Inventors Awards.

Sony Corporation. At the time of Sony's establishment, founders Masaru Ibuka and Akio Morita wrote that introducing science education into elementary schools was key to rebuilding Japan in the aftermath of World War II. This belief guided the establishment of the Sony Foundation for Education, which has offered financial support for schools and teachers over the past 42 years. The Foundation's Science-Education Program for Children funds elementary and junior high schools and teachers throughout Japan, especially those who are enthusiastically fostering interest in science among children. Recently, Sony began providing assistance for public elementary schools in Mexican communities. In another program, Sony provided support for a project in South Africa called School TV Access, which is run by the South African Broadcasting Company.

www.gener.cl/comunidad/cienca.shtml
www.dow.com/about/corp/social/ei.htm
grants.hp.com/us/programs/science_leadership.html
www.sony.net/SonyInfo/CCA/kodomo.html#p1

class research, and they are often committed to outreach activities as well. It is essential to strengthen the capacity of universities to admit aspiring young scientists and engineers from around the world.

Institutions of this type in the developing nations can play an especially important role for the region in which they are located. Further, cooperation among them can lead to networking among their best researchers – at national, regional, and international levels – to help educate the most promising students and provide fellowships for them. Because these are the graduates who will later be critical for the S&T capacities of their own countries, support for their work and professional development is essential. (See Boxes 17 and 18 for examples of financial support for developing-nation scientists, provided by foundations in industrialized nations.)

Science and technology education should not be limited to aspiring scientists and technologists, however, or even just to students. In addition to including S&T-culture courses in the formal education system, there should also be concerted efforts to impart this culture to the non-student public through pathways such as radio, television, online, print media, science museums, and community-development projects. In that way, the public can become sensitized to the important role of science and technology in society and their potential to help solve urgent problems.

BOX 17 Senior Fellowship Program of the Wellcome Trust (United Kingdom)

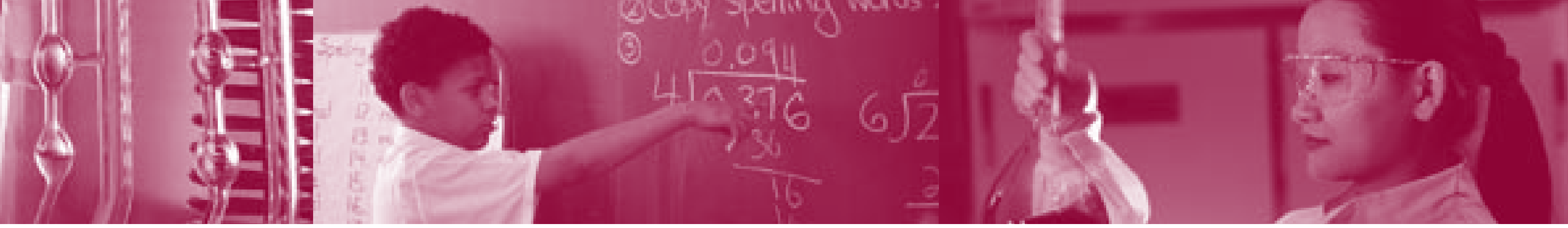
Since 1984, the Wellcome Trust has encouraged outstanding young scientists to remain in their home countries, or return from abroad, to do research. Senior Fellowship Awards are typically some £500,000 over five years and are restricted to promising researchers in the early stages of their careers. That capacity is enhanced by the prestige these awards confer in the countries where they have been established. About a dozen awards are made each year. The program currently operates in South Africa, Australia, New Zealand, and India; it is currently being extended to the Czech Republic, Estonia, Hungary, and Poland, and may in the future be extended to other parts of the world as well. The Wellcome Trust also sponsors regionally focused fellowship programs, specific to Southeast Asia, small Pacific-island states, and South Africa, whose purpose is to support scientists and health professionals who wish to develop a research program but have been unable to do so because of heavy teaching loads or lack of facilities and resources.

www.wellcome.ac.uk

BOX 18 International Foundation for Science

The International Foundation for Science (IFS) helps to strengthen the capacity of developing countries to conduct relevant and high-quality research on the sustainable management of biological resources. This field involves the study of physical, chemical, and biological processes, as well as relevant social and economic phenomena, involved in the conservation, production, and renewable utilization of the natural-resource base. The IFS supports young developing-country scientists who have the potential for becoming the future research leaders of their nations. The eligibility criteria for IFS support stipulates that the young scientists be at the beginning of their research career and from a developing country – where the research must take place. Based in Stockholm, Sweden, the IFS has 135 affiliated organizations in 86 countries, of which three-quarters are developing countries. To date, the IFS has awarded grants to more than 3,000 researchers in Africa, Asia, the Pacific, Latin America, and the Caribbean.

www.ifs.se



Recommendations

- ▶ Each nation should establish an S&T-education policy that not only addresses its own particular national needs but also instills an awareness of global responsibilities in such areas as environment, human health, and the sustainable use of the earth's resources. National education policies should particularly aim to modernize education at the elementary- and secondary-school levels (ages 5-18); and they should emphasize inquiry-directed learning of principles and skills while highlighting the values of science.
- ▶ Each government should focus resources on providing high-quality training for science/technology teachers. This will involve special efforts at all tertiary-education institutions, including research universities.
- ▶ Science and engineering academies and other S&T organizations should be involved in teacher training and the production of materials needed for students' S&T education. Scientists should be encouraged to visit schools at all levels to make well-designed presentations that promote science to the young. The InterAcademy Panel and many national academies are already engaged in such activities, and results of their experiences should be widely disseminated. The private sector also should play an active role in promoting S&T education, as it will greatly benefit from a more sophisticated workforce. Foundations and nonprofit donors could find this a most deserving area of investment as well.
- ▶ Each government should stimulate the organization of national science olympiads in different areas of knowledge, at several levels of primary and secondary education and the first year of higher education, providing resources to enable the best young talents to participate in regional and international competitions.
- ▶ Each industrialized-country government should expand its support for S&T professionals and doctoral programs in the developing nations' best universities by offering long-term fellowships with adequate stipends to deserving young people from industrialized nations who wish to do their training in world-class research programs in developing nations. Visiting professors from foreign countries should help raise the quality level of courses and research, and participate in exams and thesis defenses. Meanwhile, all universities in developing nations should strengthen their undergraduate- and graduate-degree programs in science and technology and offer fellowships to the best students.

3.2 Developing nations should develop, attract, and maintain S&T talent

Many countries, especially the developing nations, suffer from two severe human-resource shortages: an insufficient number of highly qualified scientists and engineers at universities and other research institutions; and a dearth of well-trained S&T teachers in the colleges and secondary and primary schools. A major reason for these persistent problems is the difficulty of keeping locally trained talent at home, as well as of attracting home those individuals who have obtained their degrees at foreign institutions. The brain-drain issue is a serious impediment to building and sustaining indigenous human resources.

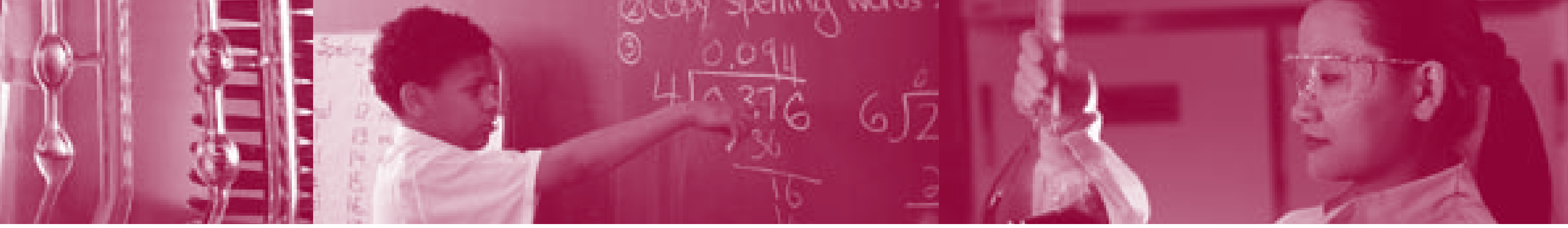
The reasons for brain drain vary from country to country, but they typically include some of the following elements:

- Poor working conditions, including the lack of basic instrumentation and technical support, particularly in the S&T-lagging nations;
- Minor importance attached to research work by the country's society;
- Limited prospects for belonging to research groups that are recognized by, and well connected to, the worldwide S&T community;
- Low probability of attaining a sense of self-fulfillment – scientific, cultural, or financial;
- Inadequate salaries;
- Weak integration of basic science and technology with public or private enterprises;
- Little or no research and development in the public and private enterprises themselves;
- Highly uncertain socioeconomic conditions for the future.

Improvement in any of these elements would certainly be useful in its own right, but all of them should be on a nation's agenda if it is to ameliorate its brain-drain problem. Chances of success in attaining such progress depend, in turn, on understanding the complex nature of the problem's fundamental causes – in the national, regional, and global contexts.

Success also depends on having a cold-eyed view of reality. It is inevitable that scientists and engineers will wish to emigrate to parts of the world where they are most likely to have promising careers. And it may be assumed that the active recruitment of talented individuals from the poorer countries to the richer ones will continue, exacerbated by the general demographic trends of aging populations in the richer countries and youthful populations in the developing ones.

Nevertheless, some nations – the East Asian Tigers, for example – have been relatively successful in addressing such basic problems, with the result that they have retained, even enlarged, their pool of S&T-competent nationals. Moreover, they have often provided stimulating ambiences for these individuals' research, and given them incentives not to look abroad,



in two productive ways: by promoting targeted initiatives in commercially promising areas of science and technology such as information and communications technology; and by facilitating the collaboration of governmental, academic, and industrial scientists and engineers for ultimately generating innovations in the country's products and services. (For a description of ambitious new program in China to recruit young science and engineering talent from abroad, see Box 19.)

It is especially important that the young talent feel appreciated by their societies, and that they be able to join the worldwide science community without having to leave home. The reward in attracting, cultivating, and retaining bright young talent is not only great but self-perpetuating: they are ultimately bound to become leaders who help change local mindsets, especially in directing the attention of politicians and their constituents to the importance of science and technology for sustainable development.

Other ways to address the brain-drain problem include programs for collaboration between the communities of expatriate scientists/engineers and their countries of origin; and a significant increase in support – financial and technical – from the receiving countries to the sending countries to help compensate them for their losses and reduce brain drain in the future by enhancing their institutions, capabilities, and opportunities.

Actually, countries that appear to benefit from a migration of scientists and engineers to their shores may not necessarily be winners in the long run unless they take some serious actions of their own. An inability to develop the needed human resources at home – basically, to 'grow one's own' – does not bode well for a healthy and sustainable path to achieving or maintaining national competencies in science and technology. These countries might actually do more for their own long-term interests, and cultivate lasting and rewarding bonds between national communities, if they helped train foreign students (along with their own nationals) while also providing incentives for them to return to their countries of origin when their training has been completed. (For a description of an international program to encourage short-term repatriation of expert consultants, see Box 20.)

Meanwhile, private and public enterprises in developing nations should enter into collaborations with academic institutions that will inevitably translate new knowledge into useful products and services. Such university-industry partnerships not only result in innovations but also create jobs and a reliable source of well-trained individuals to productively fill those jobs. This opens new opportunities for young people in these fields, helps energize the local economy, and reduces brain drain.

A related problem in almost every country, whether it counts itself among the brain-drained or not, is that many of the brains never actually left home. More than half of most countries' populations – their women – have traditionally been overlooked for important jobs or were deprived

BOX 19 China: Building a science and technology enterprise with young talent from home and abroad

The Chinese Academy of Sciences, as part of the overall national effort to increase science and technology capacity in China, is recruiting by 2005 at least 500 outstanding young academic leaders and management personnel from abroad, as well as creating 100 junior research groups to form 'group advantages' in multi-disciplinary and frontier scientific and engineering areas. By 2005, the Chinese Academy of Sciences aims to employ 20,000 permanently contracted staff and 25,000 mobile staff (including enrolled graduate students, post-doctorate scholars and visiting scholars), most of whom will be holders of PhD or master's degrees.

www.cas.ac.cn

BOX

BOX 20 United Nations Office for Project Services: TOKTEN programme

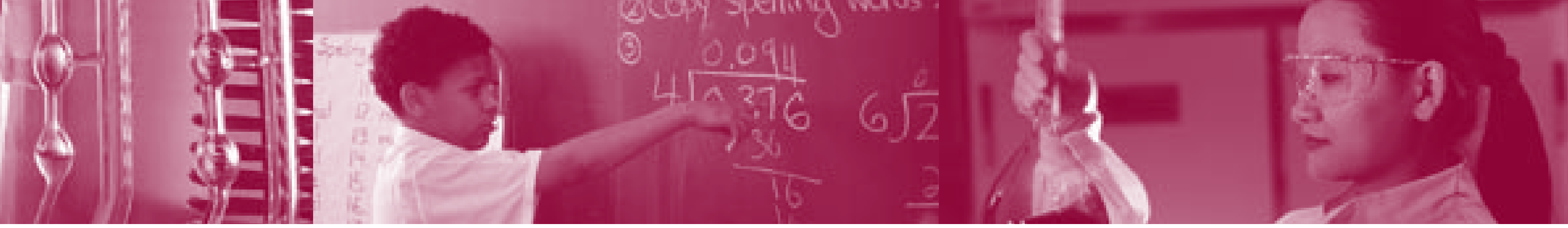
TOKTEN (Transfer of Knowledge and Technology through Expatriate Nationals) arranges volunteer consultancies by which expatriates return to their home countries to share expertise they have gained abroad at research, academic, and public or private institutions. Managed by the United Nations Office for Project Services for the past 20 years, TOKTEN projects are found in more than 30 countries. TOKTEN consultants must have at least a masters' degree or equivalent and a significant amount of professional working experience. They can hail from a range of technical fields and specializations, such as agriculture, banking, business management, computer science, economics, environmental sciences, food, geophysics, industrial hygiene and safety, marine science, manufacturing processes, medicine and public health, intellectual property law, remote sensing, telecommunications, urban studies, and water management. TOKTEN missions usually last between three weeks and three months. Consultants receive a daily allowance at applicable United Nations rates, are reimbursed for the cost of air travel between their country of residence and country of origin while on mission, and are covered by medical insurance.

www.unops.org

BOX

of the education needed to make them even nominal contenders. This has robbed countries of enormous reservoirs of talent, particularly in science and technology. Even when stereotyping or gender discrimination have largely been absent, the biological or social roles unique to women – and their consequent multiple responsibilities – have often prevented them from pursuing their careers uninterrupted or full-time during phases of their lives. Achieving greater participation of women should be a major goal in the S&T communities, and not only because it is the decent thing to do; in reality, societies simply cannot allow themselves to be deprived of the abilities and potentialities of women.

In a similar spirit, active outreach to minorities is much needed. Just as the traditional exclusion of women has deprived S&T professions, and numerous others, of half of humanity's brains, the meager representation of most of humanity's ethnic groups and cultures has hobbled progress. A great many talented individuals with much to contribute have simply not been given the opportunity to do so – sometimes out of indifference or incompetence, other times because of outright prejudice. Given its tradition of meritocracy, the S&T community should make strong efforts to eliminate such barriers by acting as pioneers and models.



Recommendations

- ▶ Governments of all countries, particularly the developing ones, should seriously consider providing, even on a temporary basis, special working conditions for their best S&T talents (whether formed at world-class research programs abroad or at home), including income supplements and adequate research support. These programs should primarily focus on young scientists and engineers, enhancing future leadership for a new era of science and technology in the country, which could ultimately improve working conditions for all of its scientists and engineers.
- ▶ Governments of developing nations, in collaboration with their national S&T communities, should establish ties with their expatriate scientists and engineers, especially those who are working in industrialized nations.
- ▶ Governments and private institutions in industrialized nations provide incentives for outstanding young researchers from developing nations to apply their skills in the service of their native lands. Recipient countries and international institutions should create or enhance programs that link these talents with efforts to develop S&T capacities back home.
- ▶ Incentives should be established to help encourage companies, especially in the developing world, to create in-house research units and hire S&T talent. Local governments could give them tax rebates or national recognition for building their human-resources capacity in science and technology (through internship programs and contracted research). More broadly, a national strategic policy to promote research and development in a country's industries, including the provision of sectoral funds (to be discussed in 6.1), should be established.
- ▶ The S&T community should develop outreach programs to:
  - Introduce girls to science during their early childhood;
  - Provide female scientists and engineers with flexible hours and opportunities for part-time work during their family-raising years;
  - Extend the periods during which critical stages of one's career – doctoral research or the seeking of tenure, for example – may occur;
  - Allow women who wish to leave their jobs for purposes such as child care to return at a later date.
- ▶ Special outreach and support programs should be promoted by the S&T community for assuring ethnic, gender, and cultural diversity. Such programs should apply to all phases of the 'pipeline,' from early childhood through graduate school and into professionals' working lives.
- ▶ Appropriate international organizations should compile reliable global and national statistics documenting trends in the international migration of scientists and engineers.

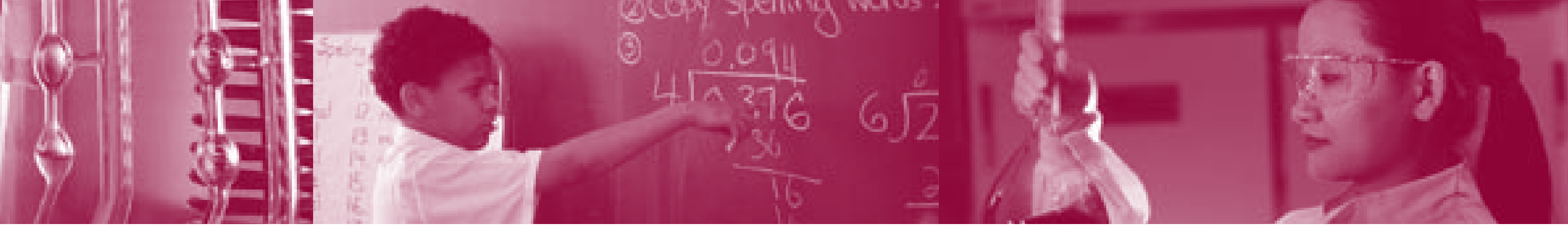
For a typical doctoral program in an industrialized nation, entering students are selected from a large pool of national and international candidates. In this process, the potential usefulness of the training for the student's home country is rarely considered. Moreover, the student's choice of a specific thesis-research topic is mostly determined by the values of the host nation. As a result, these students are trained for cutting-edge research fields that typically require expensive equipment unavailable in their home nation. Naturally, together with other factors mentioned earlier in this section, these students are unlikely to return to their country of origin after they receive their degree.

An antidote to the resulting brain drain is the university doctoral 'sandwich' program. Students begin their graduate studies at an institution in their home country, and they eventually receive their degree there. But after having selected (during an initial period of some one to two years) a thesis-research topic important to their country, they temporarily relocate to an S&T-advanced nation for a corresponding doctoral program. Given the nature of their research topic, they typically stay in close contact with their home institution and community. In that way, the students are not only well trained but likely to return home, where they can develop research problems amenable to being further pursued there. (See Boxes 21 and 22 for descriptions of successful university sandwich programs in South Africa and Sub-Saharan Africa.)

Sandwich programs thus simultaneously address the objectives of focusing on high-quality education and training; retaining S&T talent; and building international collaborations for education, training, and research.

Recommendations

▶ National governments and international organizations should provide the financial support and design the institutional framework to establish university 'sandwich programs' that provide for study in, and return from, a more advanced S&T country. These should have the following key characteristics:
- Clearly articulated program objectives,
- Competitive selection processes,
- Good monitoring and communication between advisers and participating institutions at home and abroad.



BOX 21 USHEPiA: Deepening human capital development through South-South partnerships in Africa

The University Science, Humanities, and Engineering Partnerships in Africa (USHEPiA) is a collaborative effort of nine Eastern and Southern African universities to build human capacity in science, engineering, and humanities. Initiated in the early 1990s with support from the Organization of African Unity and the Association of African Universities, USHEPiA's ultimate goal is to increase inter-institutional cooperation, building on existing potential to develop a network of African researchers capable of addressing the developmental requirements of Sub-Saharan Africa. Incipient institutional linkages were solidified by creating coordinating office for the project at the University of Cape Town and funds were garnered from the Rockefeller and Carnegie Corporations, and from private enterprise. The program has sponsored post-graduate fellowships for staff development, sandwich master's and doctoral programs wherein students work on issues of local concern, faculty and research exchange programs, short courses and joint research projects. Cohorts of grantees were selected in sciences and engineering starting in 1996, and humanities and social sciences in 1997. Forty-six full degree fellowships have been awarded to date. Sixteen PhDs and 5 master's degrees have been obtained, while 19 fellowships are on-going. Half the fellowships in the humanities have gone to women. In sciences and engineering, women account for 29 percent of fellows – not ideal, but generally above international standards for female enrollment ratios in science and engineering. Only one successful fellow is not working in his or her home country after completing the program. USHEPiA's success has been attributed to thorough advanced consultation among stakeholders, carefully defined and agreed objectives, and, especially, high-level cooperative management backed by local management and support. The program is also recognized for the enthusiasm it generates and for its impact beyond the individual fellows, two hallmarks of effective capacity-building initiatives.

www.uct.ac.za/misc/iapo/ushepia/middle.htm

BOX 22 Programs for developing academic personnel in South Africa

The Technology and Human Resource Program. For over a decade the South Africa's Department of Trade and Industry, through its National Research Fund, has been increasing the amount and quality of human resources for research and technological development. The Technology and Human Resources Program (THRIP) puts a special emphasis on increasing opportunities for black and female students to pursue technological and research careers, while giving industry specific responses to its technological needs. THRIP is a model of successful public/private partnerships. The Department of Trade and Industry shares costs – and risks – involved in developing commercial technology through peer reviewed projects that build human resources, support competitiveness of black empowered enterprises, and/or create know-how within the small, medium, and micro enterprise sector. In the past 11 years THRIP has coordinated R1.5 billion worth of investments, 60 percent of which was provided by industry. With intensive involvement of the country's historically black universities, over 2,000 honors, master's, and doctoral degree students have received support, of which one-third were black and one-third women. Twelve hundred researchers have participated, and THRIP is credited with helping to produce more than 100 patents and 3,500 scientific publications. Behind the aggregate statistics are a growing number of successful innovations for both commercial and public purposes. THRIP plans to continue expanding efforts to reach blacks and women, promoting a diverse cadre of problem solvers available to meet South Africa's economic and social needs.

The University of Cape Town's Equity Development Program. The University of Cape Town's Equity Development Program provides an umbrella for programs that promote a more equitable academic staff in South African universities. The projects increase the pool of candidates from under-represented groups suitable for recruitment to academic positions. One subprogram, the Mellon Post-graduate Fellowship Program provides grants to cover the cost of master's or doctoral studies, including a six- or -twelve month stay at a university in the United States. The 'sandwich' study opportunity has been quite successful. Many of the programs fellows have returned to positions in universities or in government. The program has been successful in targeting fellows from high-risk socio-economic categories. The awards go a long way toward mitigating the social and financial constraints that, under normal circumstances, work to limit the success of students from these backgrounds. It is also evident that study opportunity in the United States plays a major role in strengthening student's skills and identities, exposing them to a wider theoretical terrain and to a wider range of academic role models. Detailed evaluations point unequivocally to the value the fellow place on the 'sandwich' study component of the experience.

www.nrf.ac.za/thrip
www.uct.za/departmentas/acadevegrp

BOX 23 Brazilian regional center of excellence in physics

Recife is not located in the richest region of Brazil, but the physics department of the local Federal University of Pernambuco (DF-UFPE) stands out as a center of excellence in optics, condensed matter, and theoretical and computational physics. Because DF-UFPE's graduate program has provided advanced academic training for students from different parts of Brazil and abroad, diverse Latin American scientists – numerous Colombians and Cubans, for example – now account for a significant fraction of the alumni and visiting scholars. The quality of the work done at the DF-UFPE has earned international recognition, with the result that several collaborative programs have been established with foreign institutions.

www.df.ufpe.br

BOX 24 Indian research centers

Indian Institute of Science. What began, pre-independence, as a relatively modest Indian Institute of Science in Bangalore has now grown into a 'Science City' – a center of excellence with nearly 1,400 PhD students in biology, advanced materials, atmospheric science, computer science, physics, and chemistry, among other fields. Notably, the Institute offers visiting fellowships to working scientists and doctoral fellowships to students from other developing countries.

Indian Institute of Technology. The Indian Institute of Technology (IIT) is a system of seven 'higher technical institutions' located throughout India. Serving the country since 1950, the system is modeled after the Massachusetts Institute of Technology and similarly produces the country's S&T elites for teaching, research, and industrial innovation. Each institute has a tradition of working with counterparts in particular countries. IIT Madras, for example, has long benefited from its relationships with German academia and industry. In addition, faculty members maintain collaborations with leading international research institutions and with the multinational companies, such as IBM and Philips Corporation, that have established research and development centers at IIT campuses.

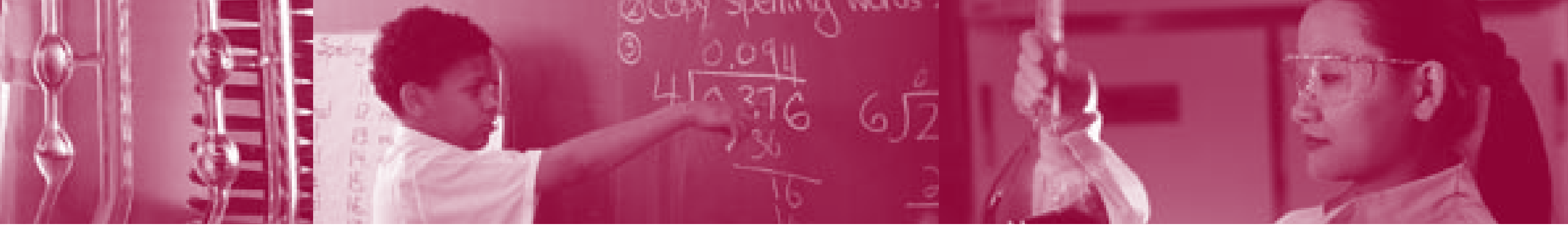
www.iisc.ernet.in
www.iitn.ac.in

3.3 S&T capacity building is a shared regional and global responsibility

In the late 1940s and 1950s several countries, in both the northern and southern hemispheres, set up new strategic programs for the development of science and technology in numerous places. The resulting strong sense of international cooperation helped nurture a new generation of scientists and engineers from a larger number of regions than ever before. In particular, young talent from developing nations went to more advanced ones to obtain their doctoral degrees or postdoctoral training and to benefit from more stimulating S&T environments. Upon returning to their original countries, they worked with other local professionals to upgrade or create institutions that later developed into centers of excellence–research programs, within a university, a research institute, or operating independently, typically located in one geographical location, and deemed by merit-review to be of the highest international quality in personnel, infrastructure, and research output.

The present call for expansion – indeed, achievement of the largest possible number – of S&T communities should enlist the abovementioned centers of excellence, located at the more advanced among the developing nations, for a fundamental role in this endeavor, both regionally and worldwide. Given their firsthand experience in overcoming many of the developing nations' typical difficulties, they are natural centers for spreading knowledge and skills to their neighbors. They should therefore commit themselves to this new enterprise by providing scholarships and opening their laboratories to talented young researchers from other developing nations. An added benefit for the latter would be an amelioration of their brain-drain problem. Their young professionals are more likely to return home from a 'South-South' exchange than from a 'South-North' one.

Brazil, China, India, South Africa, and other countries are already operating in this way, offering doctoral, postdoctoral, and visiting fellowships to scientists and engineers from developing nations in their geographic region or even from other regions. (Excellent examples are given in Boxes 23 and 24.) Some of these initiatives are carried out in partnership with the Third World Academy of Sciences (TWAS). (See Box 25 on next page.) The International Centre for Theoretical Physics (ICTP) provides opportunities for research and training to scientists from developing nations. (See Box 26 on next page.) Such programs are especially important for S&T-developing and S&T-lagging countries.



BOX 25 Fellowship programs of the Third World Academy of Sciences (TWAS)

The Third World Organization for Women in Science (TWOWS) Postgraduate Training Program for Women Scientists from Sub-Saharan Africa and Least-Developed Countries. Science, especially in the world's poorest countries, tends to be a male-dominated field. To address this imbalance, TWOWS' Postgraduate Training Program for Women Scientists from Sub-Saharan Africa and Least-Developed Countries, funded by the Swedish International Development Agency, enables women scientists to pursue a portion of their postgraduate studies at centers of excellence in developing nations. Students are required to enroll at universities in their home countries, where they ultimately earn their degrees. Meanwhile, the time spent at foreign institutions allows them to receive some advanced training elsewhere.

TWAS Fellowships for Postdoctoral Research and Advanced Training are awarded to young scientists from developing countries to enable them to spend between six and twelve months at a research institution in a developing country other than their own. Preference is given to scientists based at institutions that lack adequate research facilities. Fellowships cover international travel costs and include a US$200 monthly stipend. The host institution provides housing, food, and access to its research facilities. TWAS, in collaboration with other international science organizations, also provides additional opportunities for exchange and collaborative-research programs among developing nations.

TWAS research units in least-developed countries. In 2002, TWAS launched a new capacity-building initiative for scientific research units in least-developed countries. Recipients each receive up to US$30,000 a year over a three-year period to help improve the research environment in which they work. In the program's first year, six units were selected from among 90 applicants. These included groups that are studying Leishmaniasis disease in Ethiopia, electrochemistry and polymer science in Senegal, camel diseases in Sudan, physical and applied marine sciences in Tanzania, parasitology in Uganda, and polymer science in Yemen.

TWAS Research Grants Program. Limited access to modern equipment and the most up-to-date literature often prevents scientists in the developing world – researchers who have already made significant contributions to their fields – from taking their investigations to the next level. The TWAS Research Grants Program awards US$10,000 to established scientists for the purchase of equipment, material, and scientific literature that researchers often require at such critical junctures in their careers. Grants are given in biology, chemistry, mathematics, and physics.

www.twas.org

BOX 26 Abdus Salam International International Centre for Theoretical Physics (ICTP)

Research and training activities at the International Centre for Theoretical Physics (ICTP), a UN-affiliated organization based in Trieste, Italy, focus on a broad range of topics in theoretical physics and mathematics and in fields in which physics and mathematics serve as major analytical tools. Research activities are at the postdoctoral level and serve as career support for scientists mainly from the developing world. Each year, ICTP organizes about 40 activities – schools, courses, workshops, and seminars – that attract more than 4,000 scientists. The ICTP, in short, has become a 'home away from home' for many researchers from developing nations.

www.ictp.trieste.it

BOX 27 **Brazil-France agreement in mathematics: a new model**

The Brazil-France Agreement in Mathematics, signed in 2000, is based on the following features:

- Long-range and encompassing scientific program jointly established by both communities and reviewed every four years.
- Eleven main nodes, or centers, in each country connect to other centers elsewhere, thereby forming a global network.
- Specific efforts are decided on and implemented by a committee consisting of five mathematicians from each country.
- Results are shared with Latin American mathematics communities.

The project is under the umbrella of both the Brazilian and French ministries of science and technology, with the support of their ministries of foreign affairs. It is promoted by the national research councils of both countries – the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) in Brazil and the Centre National de la Recherche Scientifique (CNRS) in France. The agreement has been very successful thus far and is becoming a model for collaborations in other areas of knowledge.

www.impa.br/Coop_Br_Fr

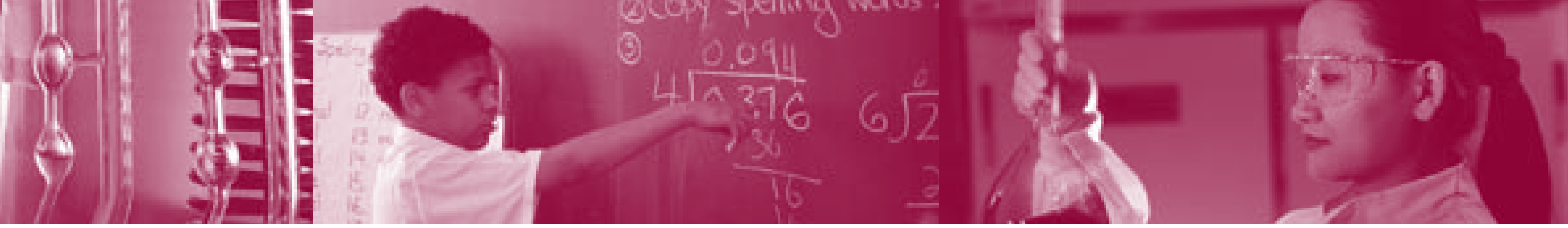
These centers of excellence should share with neighboring countries the results of their scientific and technological cooperation with the industrialized nations and the lessons learned from the latter in nurturing young scientists and engineers. (See Box 27 for a new model for such multinational scientific cooperation.)

Industrialized nations themselves could directly impart such knowledge with efforts of their own, such as programs that establish temporary adjunct-faculty/research positions at some of their universities and laboratories for scientists and engineers from other countries, particularly the developing ones. A good precedent is a German program, in operation over the past decade, that placed Russian researchers in German institutes for three-month positions (at German salaries), whereupon they returned home. This experience, which put them at the forefront of research, could then be of benefit to their Russian colleagues as well.

A prominent example of such an effort that is graduate-student oriented, of longer duration, and located wholly within southern Africa is the Research Initiative of the University Science, Humanities, and Engineering Partnerships in Africa (USHEPiA) – a network of eight universities in Sub-Saharan Africa.[14] In part to stem the brain drain and promote 'brain circulation' within the region, USHEPiA has identified and formulated a number of significant multi-institutional and multidisciplinary project proposals addressing HIV/AIDS, tuberculosis, and malaria, including the development of appropriate drugs using African natural resources. Participating institutions in the anticipated network, focusing on infectious diseases, would together offer world-class facilities and expertise for the training and deployment of health-science researchers. The network would be coordinated by the University of Cape Town's Institute of Infectious Disease and Molecular Medicine.

USHEPiA, and other partnerships like it – the African Economic Research Consortium (Box 28 on next page.), for example – focus on knowledge and how best to generate, share, and apply it to local development problems. In addition, these programs can make significant contributions to the global knowledge pool, illustrating the notion that knowledge needs to flow in all directions, including from developing nations to industrialized nations. The wealth of international expertise, when combined with strengthened local research and innovation systems, can establish a sustainable path to closing both global and local knowledge divides.

Such efforts can be complemented, and much facilitated, by the tools of new information and communications technology, which has put the S&T community in a better position than ever to make international cooperation a practical reality. In particular, scientists and engineers located anywhere can be networked for exchanging information and pursuing joint research. Information and communications technology can also play an important



BOX 28 African Economic Research Consortium

The African Economic Research Consortium (AERC) was established in 1988 to enhance the capacity of economic researchers in Sub-Saharan Africa to conduct policy-relevant economic inquiry, to promote retention of such capacity in Africa, and to encourage its application to public-policy formulation. The AERC sponsors two major activities: The research program seeks to improve the technical skills of local researchers, allow for regional determination of research priorities, strengthen national institutions concerned with economic policy research, and facilitate closer ties between researchers and policy-makers. The training program augments the pool of economic researchers in Sub-Saharan Africa by supporting graduate studies in economics, as well as improving the capacities of departments of economics in local public universities. The training program features the Anglophone Collaborative Master's Program that brings together a network of 20 universities in 15 countries. This collaboration results in a more effective use of limited teaching capacity, provides a critical mass of students, allows a larger menu of electives, and jointly enforces high standards for graduate training in economics. Similar initiatives in the Francophone countries and in Nigeria originate from the AERC studies and are based on the same concept. The AERC is supported financially by donor governments, private foundations, and international organizations. Governed by an international board, the AERC is headquartered in Nairobi, Kenya.

www.aercafrica.org

BOX 29 OpenCourseWare program, Massachusetts Institute of Technology

The objective of the Massachusetts Institute of Technology (MIT) OpenCourseWare (OCW) program is to make the materials used in the teaching of almost all of MIT's undergraduate and graduate courses available on the Web, free of charge, to any user anywhere in the world as long as the information is applied to non-commercial purposes, such as research and education. One of the program's main goals is that these course materials be of value in developing countries trying to rapidly expand their higher-education systems. In that spirit, another OCW goal is for other leading universities to adopt this model, which facilitates dissemination of knowledge and collaboration among scholars both at home and around the world and contributes to the 'shared intellectual commons' in academia. The MIT OCW is not meant to replace degree-granting higher education or for-credit courses but simply to provide the content that supports an education.

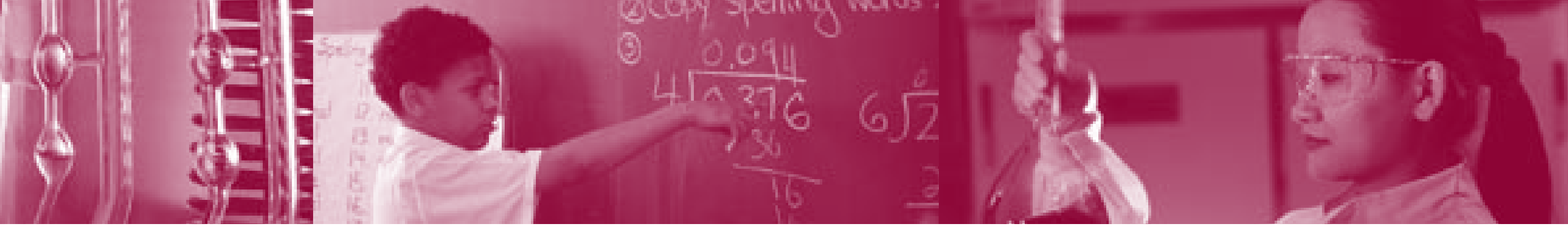
www.ocw.mit.edu/index.html.

role in developing human resources through such institutions as virtual universities. In addition to providing mechanisms like distance-learning and video conferencing, they enable 'anytime, anywhere' access. (See Box 29 on previous page for information on a major U.S. research university's innovative program that provides course materials online.)

Special programs and support from industrialized nations and the S&T-proficient nations are especially indicated for scientists and researchers working in politically or economically troubled and war-torn areas of the globe. These professionals, often isolated from the rest of the worldwide science community, are able to provide, by virtue of their scientific training and values, local voices for modernization and science-based public policy.

Recommendations

- Regional cooperation in science and technology training that leads to doctoral degrees, together with postdoctoral programs, should be promoted in national or regional centers of excellence, especially those that are in S&T-proficient countries among the developing ones. In particular, such centers of excellence should provide scholarships and research facilities, including the use of their own laboratories, to help achieve international cooperation with and among developing nations. They should also take into account the often-critical need for travel money. Bilateral agreements between S&T-advanced and S&T-proficient countries should also allow for participation of scientists and engineers in neighboring S&T-developing and S&T-lagging countries.
- S&T-advanced nations should create programs that establish short-term adjunct-faculty/research positions at some of their universities and laboratories for scientists and engineers from developing nations.
- Networks that have already been established in diverse specialties should aid in the training of new scientists and engineers. These networks should be given enduring support by academic, governmental, intergovernmental, and private organizations.
- Several programs and fellowships to support S&T capacity-building activities have previously been established by some countries and by organizations such as UNESCO, the Third World Academy of Sciences (TWAS), International Centre for Theoretical Physics (ICTP), and International Council for Science (ICSU). A database of all such activities should be created and posted on a Website, thus making the information available to all scientists and engineers, even those working in the remotest regions of the world.



3.4 Digital libraries of S&T can bring knowledge to everyone, everywhere

Scientists and technologists in developing nations have limited access to recent research findings (mostly in journals), to reference materials (mostly in libraries elsewhere), and to databases (some of which are proprietary); and these problems have been exacerbated over the past decade as information streams turned into torrents. The enormous advances in information and communications technology have opened up opportunities for remedying the situation as never before, though these same advances have also raised issues of intellectual property rights. The Study Panel nevertheless believes that the proper harnessing of digital technologies is essential to S&T capacity building in the developing nations, which should make major efforts to provide adequate infrastructure and trained technical personnel in information and communications technology for their learning and research institutions. (See Boxes 30 and 31 for descriptions of two new efforts to provide S&T information and publications to developing nations.)

BOX 30 Science and Development Network (SciDev.net)

The ability of developing countries to use science effectively depends on several factors. One is access to knowledge about the science and technology that is relevant to their needs. This requires that such knowledge is made available in an accessible form, and that developing countries build the capacity to communicate it effectively to those who need it. The Science and Development Network (SciDev.Net) is a London-based organization that was set up in 2001 to address these needs. Its main activity is the operation of a free-access Website that offers up-to-date news, views and information on science-related issues that impact on the economic and social development of the developing world. This activity is support by the science journals Nature and Science, both of which provide access to relevant articles from their pages, as well as the Third World Academy of Sciences. An important component of the Website are 'dossiers' that provide a collection of authoritative articles and resources on topical issues such as climate change, intellectual property, genetically modified crops and the ethics of clinical research. In addition to its Website, SciDev. Net is building up a series of regional networks of individuals and institutions that are keen to enhance the professional skills of those in the media, research and policy communities engaged in the communication of information about science. It also organizes regular capacity building workshops throughout the developing world.

www.scidev.net

BOX 31 International Network for the Availability of Scientific Publications

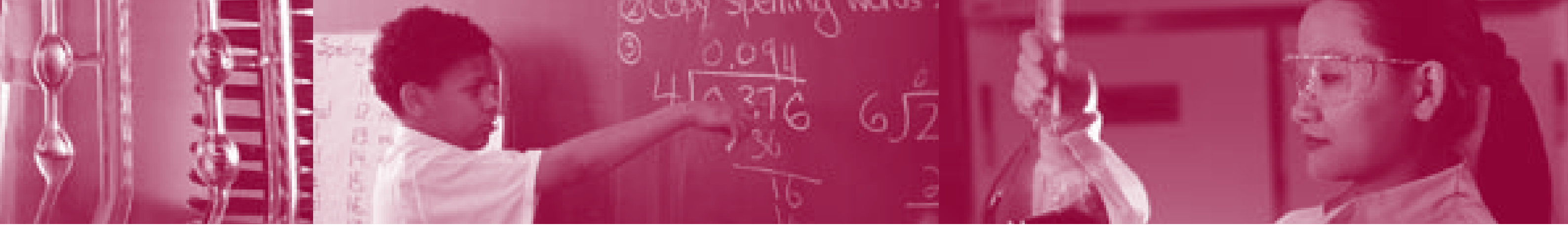
The Programme for the Enchancement of Research Information (PERI) supports research capacity in developing nations by delivering information; disseminating national and regional research results; enhancing information and communications technology skills; and strengthening local publishing. PERI supports capacity-building projects in Africa, Asia, Latin America, the Caribbean and the Newly Independent States. PERI is a program of the International Network for the Availability of Scientific Publications (INASP), a cooperative network of partners to enhance the flow of information within and between countries, especially those with less developed systems of publication and dissemination. The INASP was established in 1992 by the International Council for Science (ICSU), as a program of the ICSU Committee for the Dissemination of Scientific Information.

- PERI provides access to over 11,500 full-text online journals and many of the world's leading bibliographic and reference databases.
- INASP, through the PERI program, is assisting the establishment of online services to enable the results of research undertaken and published locally to become more widely known and accessible. One successful model that has been developed is African Journals OnLine (http://www.inasp.info/ajol). Other similar initiatives in other regions are under development to increase worldwide knowledge of indigenous scholarship.
- PERI also provides many opportunities for enhancement of information and communications technology and publishing skills through workshop series, study visits and 'mentorships'.

www.inasp.info
www.icsu.org

Recommendations

- ▶ Information needed to promote and build S&T capacity – subscriptions to professional journals, for example, and textbooks – should be made available on the World Wide Web for free, or at modest cost, to scientists and engineers from developing nations. The InterAcademy Panel (IAP), International Council for Science (ICSU), UNESCO, World Bank, regional development banks, and foundations should all promote this fundamental objective.
- ▶ Efforts to provide digital copies of back issues of scientific and engineering journals should be intensified, and the full range of these materials gradually posted for free and universal access, with a focus on reaching S&T professionals in developing nations.
- ▶ The print journals presently publishing should be encouraged to post selected articles in electronic form concurrently with their paper publication; and to reduce the time between the appearance of the latest issue of the journal and its posting.
- ▶ A major international effort should be supported to ensure that a digital-format basic-science library is made available to libraries in developing nations.
- ▶ As much as possible of the scientific, engineering, and medical literature should be put in digital form on the World Wide Web for access from remote areas. In that spirit, new approaches should be explored for replacing copyrights with more suitable ways of protecting IPR and rewarding innovators, while supporting the public interest in having broad and rapid access to knowledge.
- ▶ Major hubs in the developing world should be organized for sharing digital information with research institutions in the industrialized world. This will facilitate access to some materials (in video format, for example) that require a wide bandwidth not necessarily available everywhere. It will also serve the eminently sensible goal of backing up original material.
- ▶ Libraries should maintain electronic gateways for the sharing of digital information among researchers, teachers, and learners.
- ▶ Interlibrary loans in electronic form should be encouraged in the interests of efficiency and effectiveness. Various ways to ease fears of excess copying, from using established conventions to self-limiting or time-bound software, should be explored.



4. Creating world-class research institutions

Science and technology (S&T) capacity building requires a focus on institutions. Individuals, no matter how brilliant, cannot function without a fundamental framework for research, access to colleagues (including newly minted next-generation practitioners), and technology transfer.

Over the last century or so, the industrialized nations created a number of institutional mechanisms that together have evolved into a complex of mutual support for science and technology. Though their features may vary from country to country, they are generally of the following types:

- An educational system that promotes an appreciation of science and technology and a respect for rationality and the values of research;
- A system of universities and research centers;
- Independent academies of sciences, engineering, and medicine;
- Ministry or equivalent executive-branch structure for guiding decision-making on matters of S&T policy;
- Professional and other associations that serve the practitioners of various disciplines;
- Public funding mechanisms for promoting public-goods and fundamental research;
- Private-sector entities that are active in the promotion of new science and technology;
- Private funding mechanisms, such as foundations;
- Libraries, museums, and other cultural institutions that have archival responsibilities, as well as educational functions;
- Appropriate committees in the legislative branches of government for addressing S&T issues;
- Specialized journals and public media outlets that engage these issues at various levels.

While industrialized nations usually possess each of these institution types, many developing nations lack one or more of them – deficiencies that need to be corrected. Unless developing nations, particularly the more S&T-lagging among them, acquire such institutions along with suitable mechanisms for their effective interaction, it will be very difficult to promote S&T capacity, and to achieve sustainable form of economic development.

Specifically, the Study Panel members are convinced that each country should have, at a minimum, the following key institutions to successfully promote science and technology:

BOX 32 Korean Centers of Excellence

Korean university-related research centers. In Korea, centers of excellence are designated and supported by the Ministry of Science and Technology. These include Science Research Centers, Engineering Research Centers, and Regional Research Centers, intended to serve as major tools for promoting research and development in universities. The Science Research Centers focus on new theories in basic science and in-depth research on natural phenomena; the Engineering Research Centers emphasize development of highly advanced industrial technology; and the Regional Research Centers stress cooperative research between regional universities and industry. The Science Research and Engineering Research Centers are selected on the basis of research quality, skills, and capability; the Regional Research Centers are chosen to achieve balanced regional development of academia-industry cooperation in research and development. To ensure the continuity of their research activities, these centers receive government funding for a period of nine years, provided that periodic evaluations (conducted every three years) show good progress. The result is that the centers, which are are considered one of the most successful research programs in Korea, have significantly raised the research profiles of the selected universities. Each center consists of about 10 faculty members and receives some US$1million per year for the nine-year duration. Because they are all part of universities, the centers are open to foreign students.

Kwangju Institute of Science and Technology (K-JIST). The K-JIST was established by the Korean government in 1993 as a new educational and research institute in the country's southeast region. The aim was to create a center of excellence in the research and development of new technologies and to produce highly qualified scientists and engineers. The Institute currently has more than 63 faculty members, and it offers master's and doctoral degrees in information and communications, materials science and engineering, mechatronics, environmental science and engineering, and life science. K-JIST is unique in that it welcomes foreign students, and all the lectures are given in English.

www.iitm.ac.in/first.shtml
www.kjist.ac.kr/new/english/index.htm

- *Autonomous centers of excellence* – research programs, within a university, a research institute, or operating independently, typically in one geographical location, and deemed by merit-review to be of the highest international quality in personnel, infrastructure, and research output;
- *Strong universities* – tertiary educational institutions for educating and training new generations of S&T talent, performing research and development in areas of societal need, and providing an independent source of information on topics of importance to the nation;
- *Virtual networks of excellence* – research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the internet and the World Wide Web, deemed by merit-review to be of the highest international quality in personnel, infrastructure, and research output;
- *Independent national or regional academies of science, engineering, and medicine* – member-based autonomous institutions, in which peers elect new members in recognition of their distinguished and continuing professional achievements, elect their own officials, perform programs of independent work, and inform the general public and national decision-makers on science and technology aspects of public policies.

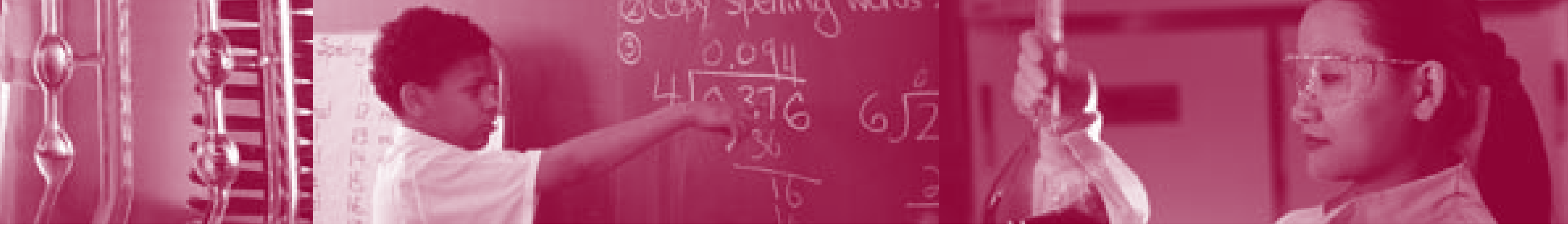
Creation of each of these four types of institutions is discussed in the following subsections.

4.1 Autonomous centers of excellence address local challenges

Science and engineering advance largely at centers of excellence – physical locations where research and advanced training are carried out, often in collaboration with other centers, institutions, and individuals. Centers of excellence are the key to innovation, and their importance cannot be overstated. Most of them are located in national laboratories or elite universities that tend to win most of the competitive research grants. For example, in the United States, with over 4,100 colleges and universities (more than 2,100 four-year universities), the top 100 universities account for US$22 billion of the overall US$27 billion in academic research expenditures. A similarly small group also accounts for the vast majority of patents.[15]

For the S&T capacities of developing nations to grow, therefore, they too should have centers of excellence – whether of local, national, regional, or international status. Such programs should have the following characteristics:

- Institutional autonomy and sustainable financial support (allowing freedom of intellectual pursuit without dogmatic or political pressure, as well as administration in a flexible and nonbureaucratic manner);



- Leadership by a person widely recognized by peers and who possesses effective management skills;
- Mechanisms for ensuring quality, including international assessments and dissemination of research results in internationally recognized publications;
- Merit-based hiring and promotion policies;
- Peer review of activities, both internal and external, as a systemic element;
- Collaboration with international institutions;
- A focused research agenda that includes interdisciplinary themes;
- Activities that cover not only research but also applications and technology transfer;
- Nurturing of new generations of S&T talent.

(See Boxes 32 and 33 for descriptions of first-rate research programs created in South Korea and Egypt.)

These centers of excellence do not necessarily have to be created *de novo*. The bolstering or reform of a country's most promising existing research and development programs can achieve the desired outcome. Better use can certainly be made of the public research and development institutions, often housing vast but underutilized armies of staff, that are now in place in many countries around the world. Many will be located at individual universities, and others will be of a regional character – perhaps even a network with several centers serving as the main nodes – to mobilize a large portion of the scientific community in the region. In any case, they should be based on groups characterized by scientific excellence and autonomy.

Some national agricultural research systems are repositories of enormous S&T capacity and expertise. Regrettably, many of them are prime examples of institutions in need of reform. Disadvantaged by inadequate political support, constrained budgets, and civil-service employment, they frequently cease to be more than the sum of their parts – and sometimes add up to less. Indeed, institutional entitlements for the individual laboratories or research centers of the system often become the norm, and seniority replaces performance as a means of assessing standing. The work on average becomes mediocre, even if some outstanding centers of excellence in certain parts of the system remain, as the abilities of capable scientists and technologists get stifled by the bureaucracy.

A key to promoting excellence is merit-based allocation of resources based on rigorous reviews. Given the relatively modest scientific capacity of most developing nations, such reviews – especially for decisions on new research projects – should ideally include appropriate experts from other nations who would essentially pose the following questions:

- What is the intellectual merit of the proposed activity?

BOX 33 The new Library of Alexandria

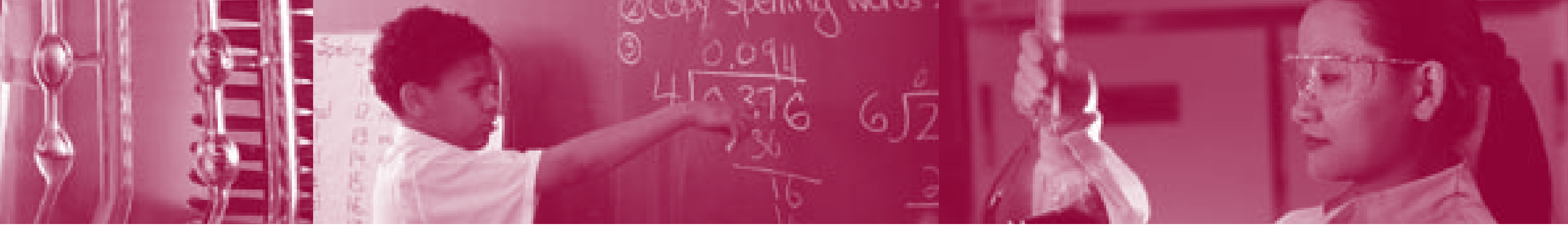
The Government of Egypt recently built the Bibliotheca Alexandrina almost on the very spot where the ancient Library of Alexandria had been the center of world learning. The Bibliotheca Alexandrina is governed by an international board committed to excellence, and its legal autonomy and institutional flexibility are unique features that allow it to move quickly into new academic programs and incorporate technological advances. Among its many programs, the Bibliotheca Alexandrina today has seven research institutes. One institute, for example, promotes collaborations between Egyptian scientists and colleagues working elsewhere, and another is helping to apply the most advanced informatics to the country's needs. The Bibliotheca Alexandrina as a whole is dedicated to promoting the scientific outlook, and though still in its infancy it has already succeeded in organizing a number of joint enterprises with eminent institutions of science.

www.bibalex.org

- How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields?
- How well qualified is the proposed individual or team to conduct the project?
- To what extent does the proposed activity suggest and explore creative and original concepts?
- Is there sufficient access to resources?
- To what extent will the activity enhance the infrastructure for research and education?
- Will the results be disseminated broadly to improve scientific and technological understanding?
- What might the benefits of the proposed activity be to society?

Similarly, all ongoing research programs at centers of excellence will benefit from a periodic expert review and evaluation. Techniques for such procedures include the following:

- *Peer review teams* are composed of scientific or technological peers who have the essential knowledge and perspective to judge the quality of research. Their reviews should make judgments about individual researchers, the value of their contributions, the management and standing of research institutions, and the allocation of funds to individuals and fields of research.
- *Relevance review panels* are composed of scientists or engineers from the field of research, experts in fields related to the one under review, and potential users of the results of the research. A relevance review will judge not only whether a proposed research program supports its mission but could also indicate promising directions for future research, both basic and applied.
- *Benchmarking studies*, conducted by panels of international experts, evaluate a nation's standing relative to other nations regarding particular parts of its science and engineering research efforts. Although the principal reliance is on the judgment of experts, quantitative measures can also be used for confirmation.



Recommendations

- ▶ Centers of excellence – research programs, within a university, a research institute, or operating independently, typically in one geographical location, and deemed by merit-review to be of the highest international quality in personnel, infrastructure, and research output – should be created, or seriously planned for the near future, whether of local, national, regional, or international status, in practically every developing nation in order for its S&T capacity to grow. Such centers can serve as the main nodes for individuals or groups charged with enhancing S&T knowledge of national and regional importance.
- ▶ The centers of excellence should have institutional autonomy; sustainable financial support; knowledgeable and capable leadership; international input; focused research agendas that include interdisciplinary themes, applied research, as well as basic research; technology transfer; peer review as a systemic element; merit-based hiring and promotion policies; and mechanisms for nurturing new generations of S&T talent.
- ▶ Where such institutions already exist, they should be reinforced or, if necessary, reformed.
- ▶ When reform is indicated, changes should be systemwide and carried out in ways that make the best use of scarce resources (including the local talent).
- ▶ Where there is much talent but the system is bureaucratized, it is crucial that reform includes the following:
  - Focus on themes, not institutions (i.e., abolish institutional entitlement);
  - Build up a small but select number of centers of excellence;
  - Build up a few nodes (around groups) of top expertise with institutional support;
  - Open up the research system to competitive grants;
  - Protect public-goods research;
  - Address essential long-term national or strategic issues (e.g., environmental, health, and agricultural).
- ▶ New scientific and technological research projects should be decided on the basis of input from expert merit review, with each project and program evaluated for both technical merit and its potential benefits to society. All existing research programs and centers of excellence can similarly benefit from periodic expert merit review and evaluation. Techniques for such procedures should include, as appropriate, peer review teams, relevance review panels, or benchmarking studies.
- ▶ Given the relatively modest scientific capacity of most developing nations, their merit reviews should ideally include appropriate experts from other nations. Such involvement of the global research community, possibly through a program of international cooperation among academies of science, engineering, and medicine, can make the merit-review processes in developing nations more effective – not just for particular programs but in general.

BOX 34 National Autonomous University of Mexico

The Universidad Nacional Autónoma de México (UNAM) has been subject to all the demographic and political pressures experienced by public universities in many other populous developing countries. Yet UNAM has succeeded in maintaining centers of excellence according to the highest international standards. Despite having over 150,000 university-level students, UNAM research is at the cutting edge in several areas and is developing programs related to industry. UNAM graduates the largest number of doctoral-degree holders in science and engineering in the country and has filed the second-largest number of patents (after the Mexican Petroleum Institute). UNAM maintains a 'hands-on' science museum, managed by faculty members and science students, that receives annually over one million visitors (the majority of them youngsters). To ensure that the university's research work and graduate programs are at the highest level, scientists from the United States and Mexican academies of sciences were enlisted to review them. While the joint review was favorable, the university took to heart the committee's recommendations for further improving its performance.

www.unam.mx

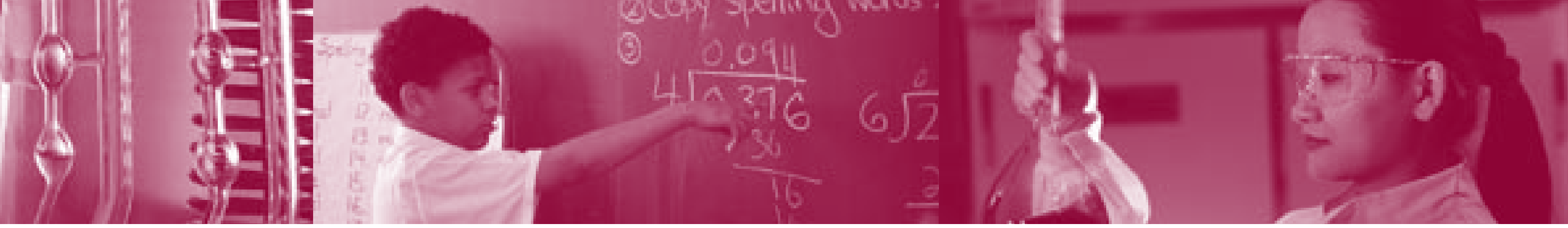
BOX

4.2 Strong universities are critical for expanding national S&T capacities

Universities are absolutely essential to the development of countries' S&T capacities. They educate and train new generations of S&T talent, perform research and development on issues of importance to the nation, and provide an independent source of information on such topics as economic development, agriculture, health, and the environment. National governments in developing nations should make a clear, continued commitment to support and encourage advanced education and research activities within universities, in partnership with independent research institutes and industry. Without such an explicit national commitment to strengthen universities, critical mass in the country's science and technology simply cannot be achieved. (See Box 34 for a description of a major university in a developing nation that maintains several cutting-edge research programs.)

Recommendations

- ▶ National and local governments in developing nations should strengthen higher education with public funds (supplemented with private funds if available) to offer greater opportunities for tertiary education and S&T training to young people in modalities ranging from 'community colleges' (as they are called in the United States) to top-class research-based universities.
- ▶ National and local governments in developing nations should develop a strong partnership with universities and industry to plan the development of capabilities in science and technology.
- ▶ Universities should have increased autonomy while seeking to systematically strengthen their ties with regional and international institutions and networks; such links can significantly increase the effectiveness of the universities' S&T efforts.
- ▶ Research universities should make strong commitments to excellence and the promotion of the values of science in their activities, incorporating unbiased merit review into all of their decisions on people, programs, and resources; they should also have greater interaction with society at large.



4.3 Virtual networks of excellence link the scientific talents of entire regions and the globe

Traditional centers of excellence (as described above) will be indispensable to developing nations, but to expedite evolution of S&T capacity they should be complemented by new structures.

An important step in this direction will be the creation of 'virtual networks of excellence' (VNE) throughout the developing world. Each VNE will mobilize groups of scientists and engineers to collaborate on projects and nurture S&T talent largely through 'virtual institutes.' Virtual institutes will be relatively small, efficient, and embrace innovative research groups anchored in recognized research centers. Though these groups may be far apart geographically, they will be closely linked to each other via the Internet. The virtual institutes created through VNE will work to blend their activities into coherent programs, yet the individual research groups will work in areas of prime interest to their own countries. (See Box 35 for a description of a relevant technology-based cooperative program among developing nations countries; and Box 36 for a description of effective regional research programs in Latin America.)

BOX 35 China-Brazil earth resource satellites

The Governments of China and Brazil created a program of collaboration among developing nations – based at the Chinese Academy of Space Technology and Brazil's Institute for Space Research – for developing two remote-sensing 'China-Brazil earth resource satellites' (CBERS). Although technology transfer was not an objective of the original agreement in 1988, subsequently, exchange of knowledge and information between Chinese and Brazilian scientists was inevitable and deliberate. The program's first satellite, CBRS-1, was launched in 1999, the second, CBERS-2, in 2003. Based on the program's success, the two countries are exploring the feasibility of jointly developing geostationary meteorological and telecommunications satellites as well.

www.cbers.inpe.br

BOX 36 Latin-American regional networks

Latin America currently has five regional basic-science networks: the Biological Sciences Network (RELAB), which has been functioning since 1975; and networks for chemistry, mathematics, physics, and astronomy that were established in 1993 under RELAB's leadership. Their purpose is to enhance Latin American science communities and strengthen their voices. Relying on national and regional scientific societies for intellectual support, and on local governments for financial sustainability, the networks' activities include short-term training, symposia, and collaborative research projects. In addition, dialogues between network scientists and governmental authorities have helped generate ideas for further developing science in the region. These networks are coordinated by a regional committee that is supported by the International Council of Science (ICSU) and UNESCO. RELAB is supported in part by foreign foundations. Another successful example is the Latin American Network of Botany, which has obtained support from foreign foundations for collaborative research and training activities.

BOX 37 Millennium Science Initiative

The Millennium Science Initiative (MSI), with major funding by the World Bank, seeks to strengthen science and technology capacity in developing countries. It supports locally planned and executed programs that provide new opportunities for talented scientists to excel through research, training, networking, and outreach. Core qualities of the MSI include autonomy, flexibility, objective selection and evaluation, and adequate and sustained funding. Local leadership helps ensure continuity, political acceptance, and familiarity with local challenges. The successes of MSI programs in Chile, Mexico, and Brazil have shown that even limited investments in programs designed to reflect international 'best practices' can have a disproportionately large impact on a nation's performance and productivity in science and technology. New MSI programs are now being established in countries of Africa and in Vietnam. To promote MSI all over the developing world, the Science Institute Group (SIG) was created to serve as facilitator and catalyst for the program in each country or region.

- Brazilian Millennium Institutes. Two groups of MSIs have been established in Brazil through competition: Group I includes 15 science and technology institutes that could play key roles in achieving new standards of national competence in their fields, which range from mathematics to nanosciences to tissue bioengineering to the effects on climate of land-use changes in the Amazon. Group II includes two institutes that operate in broadly defined strategic areas – namely semiarid-region research and coastal research. These institutes are financed by the Brazilian government and the World Bank in equal parts, with initial backing from the Millennium Science Initiative.
- African Millennium Institutes. The African MSI focuses on three areas – biotechnology, instrumentation and information technology, and mathematics – chosen on the basis of present strengths and potential for maximum benefit to the region. The emphasis in each scientific area is on research and training, some of it through virtual means, involving institutions, researchers, and students distributed across the continent. This project has been driven by the African scientific community from the start, with institutions elsewhere playing supportive roles.

www.msi-sig.org/sig.html

The objectives of a VNE-sponsored virtual institute should be as follows:

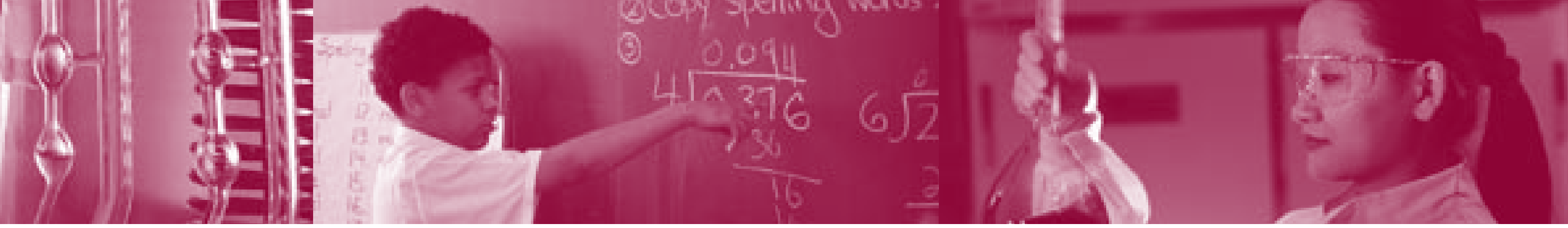
- Deepen competence in important areas of science and technology through broad national, regional, and international activities;
- Establish ways to transfer generated knowledge to the public and private sectors, thus helping to solve important social problems and improve the competitiveness of the country's industries;
- Promote interdisciplinary projects;
- Contribute to solutions of global problems that could have significant impact on the country;
- Promote regional science and technology partnerships;
- Help in the professional growth of talented young researchers.

A VNE should create virtual institutes that embrace these two qualities. First are those that deepen researchers' competence in their respective fields, forge new collaborations with colleagues elsewhere (both in and across fields), and help to form an essential basis of S&T knowledge for social and economic advancement. The second are those that directly address strategic themes for national development, such as enhanced productivity and competitiveness, through the direct application of scientific knowledge and technological know-how.

Either way, each virtual institute will be coordinated by a researcher of exceptional repute who is responsible for its research efforts and administration. It will be housed at a host institution that provides adequate resources, both human and material. In the case of multi-institutional teams, all entities involved should guarantee effective support for the project's participants in their purview.

Although the resources for establishing a VNE can be considerable, the benefits may well be worth the costs to funders. And while the main focus here is on the developing world, such virtual networks can serve the S&T-advanced countries, and the world, as well. Because of modern communications, virtual networks of excellence are a convenient way today to mobilize scientific and technological communities – wherever they may be – for addressing issues of national, regional, or international interest.

An important instrument in the promotion of virtual networks and, in some cases, centers of excellence themselves, is the Millennium Science Initiative that has recently been established in Brazil, Chile, and Mexico with strong support from the World Bank and local S&T communities. Such a Millennium Science Initiative is also to take root in Vietnam, and several others are being planned for Africa as well. (See Box 37.)



Recommendations

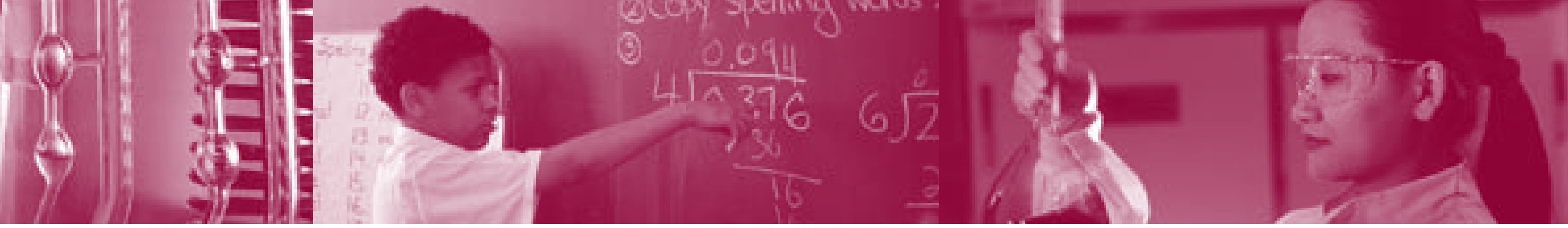
- ▶ Virtual networks of excellence (VNE)-research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the Internet and the World Wide Web, deemed by merit-review to be of the highest international quality in personnel, infrastructure, and research output – should be created nationally, regionally, and globally.
- ▶ Emergent centers of excellence should be involved in virtual networks of excellence.

4.4 National academies of sciences, engineering, and medicine can improve the quality of national S&T programs

National academies, as defined here, are member-based autonomous institutions, in which peers elect new members in recognition of their distinguished and continuing professional achievements, elect their own officials, perform programs of independent work, and inform the general public and national decisionmakers on science and technology aspects of public policies. The presence of such institutions is extremely important for upholding the quality of S&T activity in a country, for guiding national policies based on science and technology, and for maintaining dialogue with other countries, often through their counterpart academies.

Recommendations

- ► Every country should have national academies of sciences, engineering, and medicine – member-based autonomous institutions, in which peers elect new members in recognition of their distinguished and continuing professional achievements, elect their own officials, perform programs of independent work, and inform the general public and national decisionmakers on science and technology aspects of public policies.
- ► For those countries without a critical mass of active scientists or engineers, the creation of national academies may not be possible. In such cases, academies should be built on a regional rather than a national basis. The formation of professional societies should also be promoted.
- ► International institutions, such as the Third World Academy of Sciences (TWAS), InterAcademy Panel (IAP), International Council for Science (ICSU), Council of Academies of Engineering and Technological Sciences (CAETS), and InterAcademy Medical Panel (IAMP), should continue to facilitate the formation and strengthening of nascent national and regional academies of sciences, engineering, and medicine. The forceful participation of these international bodies will help new organizations establish the requisite high standards and effective mechanisms of operation.
- ► Academies should actively participate in national and international debates to make the voices of the S&T community heard on a broad range of issues.



5. Engaging the public and private sectors

For-profit organizations – propelled in large part by the globalization phenomenon that favors the fast, the nimble, the businesslike, and the educated – have now become the world's predominant force in applying science and technology (S&T) to the production and distribution of new goods and services. In 2000, the private sector's share of investments in research and development worldwide was 62 percent.[16]

This dominance is likely to continue and expand in the foreseeable future, although the private sector in the developing world is not yet significantly contributing to research and development. Actually, it is important to recognize that in many developing nations the most important entities involved in research and development may well be publicly owned for-profit entities, which frequently have the capacity to be viable partners in ventures of research and development and may be quite competitive in regional markets.

The indigenous industrial sector, whether private or public, is especially important to the economic growth of developing nations: its activities create greater employment opportunities for skilled workers, along with increased demand for scientific and engineering education. Thus a positive-feedback mechanism can be established for greater knowledge, more entrepreneurship, additional products and services, a continuing increase in employment opportunities, and a consequent demand for yet more knowledge.

While many decry the inability of countries in the developing world to create such mechanisms, it is worth noting that some of the greatest success stories of our time – Singapore, South Korea, and Taiwan – are cases in which harmonization with globalizing trends was extensive. And the national policies of these countries not only favored export promotion but set high priorities for the education and research and development that would make it possible. Such national commitments have served these countries well; in South Korea, for example, per-capita income rose from US$1,325 in 1960 to US$11,022 in 1998 (in constant 1995 dollars). Even more stunning, that nation today outspends both Italy and Canada in research and development.[17] Southeast Asian countries hope to follow a similar path.

The actual influence of a nation's for-profit private sector is strongly affected by an enabling environment for business. And investment in research and development by for-profit firms is heavily dependent on the

existence of strong intellectual property protection for patents, allowing a company to make a financial return on their S&T investments. But the enormous urge to patent has also created a litigious environment and complex rules that are difficult to follow. In addition, this trend is increasingly fomenting secrecy in research and a limitation of access to scientific and engineering data. This not only stymies serious debate on ethical questions – those regarding the 'the new biology,' for example (Section 5.3) – but as the tools of research themselves become patented it limits the ability to do public-good research.[18] Meanwhile, as the current notions of intellectual property rights are being challenged by the digital technologies of the information and communications revolution, the availability of new electronic hardware and software – so integral to the spread of science and technology capacity in many areas of the world – is much less than what it should be.

To assure that these situations play out constructively, the existing intellectual property regimes should be revisited in order to ensure adequate returns to the innovators while providing for the needs of the developing nations and stimulating public-good research.

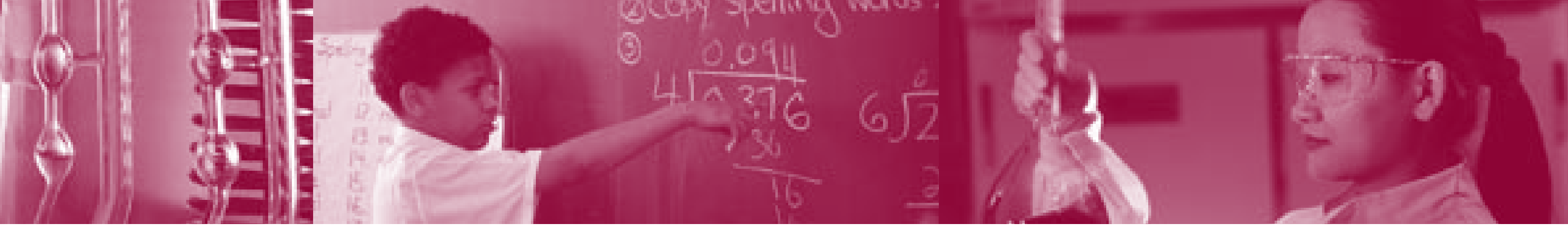
Issues related to the private sector's role in building S&T capacity, and to that goal's dependence on pragmatic policies regarding intellectual property rights, are discussed in the following three sections. They address frameworks for the public-private interface; public-private partnerships; and collaborations with the international private sector.

5.1 Clear legal frameworks promote successful public-private interaction

Globalization does not occur in a vacuum. It results from numerous agreements between sovereign nation-states that are the principal actors in international legal and financial systems. State-sanctioned isolationist impulses, by contrast, can result in disaster for a country's citizens as its S&T capacity, and hence its competitive position and economic health, wither on the vine.

It is also essential to recognize that for the private sector to keep on contributing to the development of S&T capacity, the public sector should maintain an enabling environment – local, national, and international. Meanwhile, governments should provide regulatory frameworks to protect the public interest and safety, and fund research and development efforts for public goods.

Because these roles interact in complex ways and can sometimes clash, it is important to define a framework for the public-private interface so that each party is sufficiently aware of its domain's boundaries and where it may overlap with that of the other. The national legal structure should be clear and predictable. It should define the pertinent health and safety regulations as well as the labor and financial aspects that affect the activities



of the private sector. The legal structure should also provide incentives for foreign partners to undertake technology transfer to the indigenous private sector. And it should provide incentives to build active technology centers in developing nations that link to the local university system, thereby helping to create opportunities for the training and support of future scientists and engineers.

Recognizing that there is no single formula – every country, in every field, has its own specifics – such a framework should include the following:

- *Definition of the scope of the public domain and the maintenance of public spending for public-goods research.* From the time of 18th century Scottish economist Adam Smith, it has been known that the private sector will not invest in public goods, despite their demonstrable value to the public. It is not a private company's function to do so.
- *Definition of the boundaries of the public and private domains so as to take maximum advantage of the complementarities and reduce the overlaps.* Careful decisions here would also lay the groundwork for more and increasingly effective public-private partnerships; and they would uphold the primary roles of entities such as research universities, public research laboratories, and small local companies as well as the large multinationals. The special position of private nonprofit foundations should also be taken into account.

Recommendations

▶ Every country should develop a clear, predictable legal framework with regard to the activities of the private sector. This framework should be compatible with the national S&T policy while providing incentives for real technology transfer. Recognizing that there is no single formula – every country, in every field, has certain specifics – such a framework should include the following:

- Definition of the scope of the public domain and the maintenance of public spending for public-goods research.
- Definition of the boundaries of the public-private domains so as to take maximum advantage of the complementarities and reduce the overlaps.

▶ S&T-developing and S&T–lagging nations should consider regional and multilateral cooperation and sharing of resources for implementing intellectual property protection, so that poor countries with limited technical resources do not have to duplicate effort, investment, and dedication of scarce talent.

5.2 Public-private partnerships are critical if science and technology are to benefit society

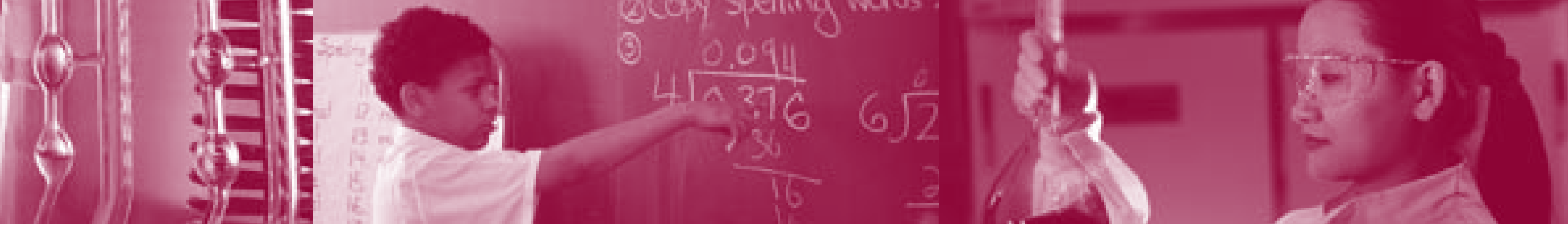
The Study Panel believes that to bring the benefits of scientific discoveries and technological innovations to all of the world's people, imaginative and vigorous forms of public-private collaboration should be actively promoted. Such partnerships can invigorate education, conduct research of mutual interest, and capitalize on the results of the research for the benefit of society. But because it has not traditionally been in the interest of private companies to share their resources and creative competencies with the public sector, incentives are needed. This can be accomplished through a variety of means, including tax advantages to firms for cooperative research, commercialization of publicly financed research, 'scientist-in-industry' programs, joint or specialized training, and technology parks and publicly supported 'incubators' for providing start-up companies with assistance such as office and laboratory facilities and technical support.

Public-private partnerships will likely focus on pre-competitive work, leaving product development to the private sector alone. Industry should of course share the costs; and given its organizational advantages, it should take the lead in these cooperative research initiatives. Conversely, work on programs of public goods should be supported by public funds and possibly undertaken by the public sector alone, or with private contractors working for the public.

Importantly, the effectiveness of both public research programs and public-private partnerships depends in large part on two related factors: the provision of sufficient public funds to areas of nationally relevant research, and the education and training of indigenous professionals capable of fully participating.

Another enabling factor is the role change that most national governments are undergoing. They have been transcending their traditional functions to also become facilitators, funders, collaborators, and information resources for all research institutions – whether public, private, or public-private. The latter role is especially critical for governments in developing nations; each should be making long-term investments in a local and effective 'knowledge-based infrastructure' – the nation's entire system that supports private entrepreneurship, human resources, investment, and exploration of the advancing frontiers of S&T knowledge. Developing-country governments should also be delivering technology and training services of their own (e.g., through community and technical colleges).

The nature of the modern research enterprise and the speed at which its results get turned into marketable goods and services are creating new roles within research institutions. For example, some universities in industrialized nations have allowed investigators the freedom to own equity in



companies based on their patented discoveries and to share in the resulting profits. Institutions may even help faculty in negotiating agreements with industry. At the same time, excessive faculty involvement in off-campus activities can weaken the institutions' teaching and basic-research functions. There clearly needs to be a balanced approach. It should be noted, moreover, that workable approaches in one field or institution may not be appropriate to another.

Recommendations

- ▶ Governments, industries, universities, and research institutes in developing nations should experiment with partnerships and consortia for addressing research areas of potential local benefit.
- ▶ Government in particular – both national and local – should play a central role in creating public-private research partnerships.
- ▶ National and local governments should ensure that individuals and organizations continue to have strong incentives and opportunities to capitalize on research.
- ▶ Participants should ensure that public-private research relationships do not impair the core mission and values of public research institutions.

5.3 The international private sector sponsors S&T research that has great potential for addressing challenges in developing nations

New areas of knowledge, rendered explorable with the aid of new technologies, are opening up in the biological sciences. For example, the sequencing of the human genome, as well as the genomes of the causative agents of illnesses such as tuberculosis, leprosy, and malaria, have raised expectations of defining the genetic origins of major diseases and devising therapies to treat or even prevent them. Agriculture could benefit too: the genomes of rice and the laboratory-model plant *Arabidopsis thaliana* have been deciphered, and a banana-genome project is currently under way.

Increasingly, widespread application of new enzymatic processes, made possible by application of large-scale gene-shuffling and biochip technologies, is transforming many chemical industries into biotechnology-based industries. These new technologies are far more environmentally friendly, and actually more efficient, than many traditional chemical-based processes.

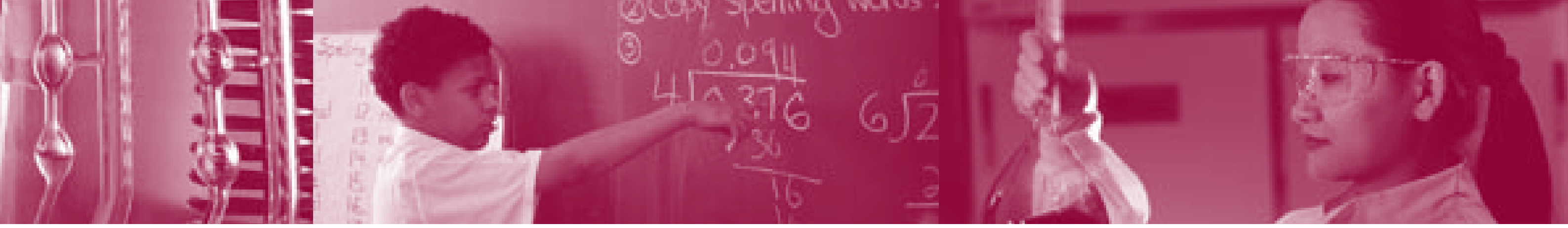
Driven by such research and development mostly in the wealthy nations, new and exciting commercial applications across the globe are likely not only in medicine and agriculture but also in environmental protection and other critical areas. This is particularly true in S&T-lagging countries because the most attractive course for the developing nations, given their initial conditions (such as the general lack of extensive laboratory facilities), could lie in embracing 'post-genomics' research strategies in bioinformatics, comparative genomics, and assessment of gene-environment interactions. At a minimum, bioinformatics networks could help those with Internet connections to access genome data for 'in silico' experiments that could later be validated in laboratories elsewhere. In that way, developing-nation researchers might apply emerging genome information to applications tailored to local developmental needs.

But while the research and development will progress rapidly, commercial follow-up may be slowed by safety concerns, such as those affecting the international transport of food products based on genetically modified organisms. The positive visions are also tempered by ethical issues of patenting human genes and the confidentiality of data on individuals' genetic characteristics.

Inequities in the access to medical treatment for poorer populations present another barrier to widespread adoption; at present, there often is little or nothing to adopt in the first place. Although the worldwide research investment in health is US$30 billion, only 5 percent of it has been devoted to the health problems of the developing nations, which account for 93 percent of the world's preventable mortality (measured in years of potential life lost). Of the 1,393 new drugs developed between 1975 and 1999, only 13 of them addressed tropical diseases of interest to the developing nations.[19]

Many of these omissions could be corrected with the advent of a favorable intellectual property regime, which the international private sector depends on to recoup its investments in research and development. But the negative aspects of the current drive to patent almost everything deserves careful scrutiny. It is leading to a privatization of knowledge that creates obstacles to developing nations' access to the tools of research – even to their consumption of the fruits of research conducted elsewhere – and can also confound international cooperative-research programs if patent-holder's lawyers and governments choose to use the rules to obstruct the new applications.

It is increasingly clear that the current system of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) is not necessarily beneficial to the developing nations, and that some judicious changes within TRIPS are in order to protect their interests while respecting the interests of the innovators.[20]



Nowhere in the domain of science and technology have these obstacles been more evident than in the patenting of drugs, particularly in the opposition of patent holders to the production of inexpensive generics, which would be of great value to the developing nations. But these patent holders – mostly the big pharmaceutical companies – have little incentive because their sales in the developing nations are a very small fraction of their total sales. This is partly because the markets themselves are small (in terms of purchasing power relative to distribution costs) and partly because markets remain inaccessible in many of these countries; the local rules are unclear, making it difficult for exporters to penetrate. Accordingly, it may be appropriate to suggest a more imaginative approach.

It is in the interest of the private sector in the industrialized nations to build up the local private sector in the developing nations, even though this may seem at first to be fortifying its own future competition. A vibrant and powerful local private sector could help create a flourishing local market, which would more than compensate the multinationals for any initial reduction in market share.

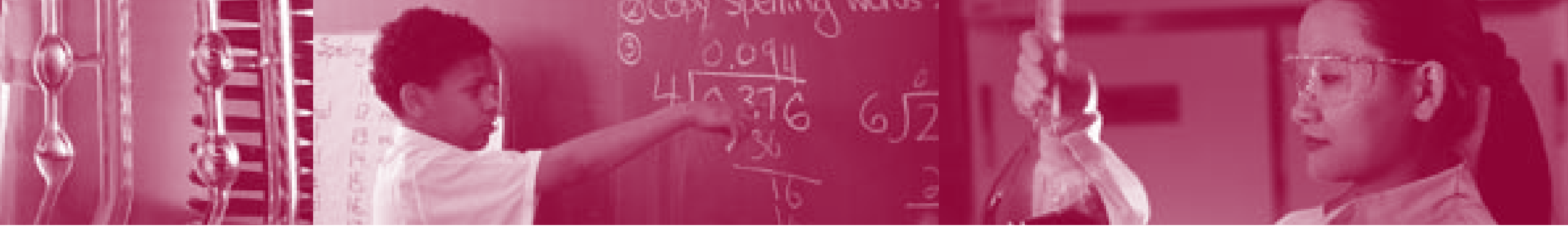
The private sector in S&T-advanced countries can segment its market to help in the development of S&T capacity building in the developing nations. These actions would not only be good for companies' images; they would also be commercially rewarding in that they would expedite a developing nation's own research and development efforts, permit the development of locally made product variations, and safeguard the market by keeping local prices of products from rising beyond the reach of most of the country's population. For example, companies in the S&T-proficient developing nations could enter into partnerships with the multinational private sector to develop inexpensive generic drugs and make them available domestically to the poorer and S&T-lagging countries, while promising not to export such generics to the richer countries, where the patented brand-name medicines would be marketed by the multinationals. The poorest S&T-lagging countries would benefit from the low-cost generics imported from the more proficient developing nations, and would be offered an extension of the grace period under TRIPS to 2016 (as recommended by the recent Commission on Intellectual Property Rights).[21]

Enormous amounts of data are becoming available through the internet, but its usability by the scientists in developing nations is blocked by copyrights and high subscription costs in foreign currencies. Indeed, the copyright regime is itself being stretched by the enormous expansion of available data online. New systems of online management need to be devised. It is important that these new systems recognize the needs of developing nations for special access to this data in order to build up their S&T capacities are not impeded. It is for this reason that the role of digital

libraries should be stressed. Accelerated, automatic-licensing agreements should also be in place to permit local efforts in research and development that use patent-protected processes and intermediate inputs in research endeavors.

Recommendations

- ▶Governments of developing nations should focus on licensing issues, accept strong intellectual property rights for new medicines, negotiate special agreements on generics for basic pharmaceutical products, promote local industry through partnerships with foreign companies, and amend their current intellectual property legislation to emphasize the genuine invention of useful technologies while putting less focus on the protection of minor or intermediate technologies and research and development processes.
- ▶Governments of industrialized nations should offer research grants for poor-country diseases, promote global health initiatives, provide tax incentives to major companies for working with developing nations and for doing automatic licensing and other initiatives, and they should support the extension of the grace period under the Agreement for Trade-Related Aspects of Intellectual Property Rights (TRIPS) to 2016 for most developing nations.
- ▶The multinational private sector based in the S&T-advanced countries should waive patent fees on the few existing patented tropical-disease drugs, and make them available for free in some cases (e.g., as with Merck's therapy for onchocerciasis and Novartis's therapy for leprosy). It should allow automatic licensing for S&T-proficient and S&T-developing countries to produce generic drugs (as long as they honor a ban on exportation of the generics to the high-income markets of the industrialized nations). And it should build real partnerships with developing nations' private sectors, consider market segmentation for the developing world, and actively encourage extensions of the grace period under the Agreement for Trade-Related Aspects of Intellectual Property Rights (TRIPS) to 2016 for most developing nations.
- ▶The national academies should become more actively involved in bringing together the private and public sectors; and they should work across sectoral and national boundaries to help promote collaboration between the industrialized and developing nations, as well as among the developing nations. Scientists and engineers can play especially productive roles here in articulating creative proposals for different countries and sectors, making available intermediate inputs in research, access to digital information online, and wide bandwidth links between public research facilities and the new digital libraries of the future.



6. Targeted funding of research and training efforts

A key feature of our time, as emphasized in this report, is the central role of science and technology (S&T) as generators of social and economic progress; they give rise to a capability to innovate, which is essential to a country's competitive position. Unfortunately, as also emphasized, many countries still lack such capability. Remedying that situation – creating or fortifying the S&T capacities of developing nations so that they may become serious participants in the world market – requires the broad intellectual commitments of leaders in the industrialized and developing nations alike. But to make these goals a reality, all should also commit themselves to building mechanisms for sufficient and sustainable funding.

Needless to say, the Study Panel believes that the overall levels of all official development assistance should be increased, and that the place of S&T capacity building should be secured among the priorities. Many existing programs for fellowships, training, and education can be expanded, as can programs of support for universities in developing nations. In addition, there are many innovative approaches being explored in the domain of international funding for development. Debt-swaps involving either foreign loan principal or interest, already used in terms of debt for nature swaps, could also be explored for S&T capacity building, as could some of the debt relief programs for the heavily indebted poorest countries, helping them to address the special recommendations for these S&T-lagging countries. Out of many other possibilities, the Study Panel has selected the following suggestions for further elaboration.

6.1 National 'sectoral' funding programs provide support for research and development of national importance

One of the most imaginative ideas in this vein is a family of 'sectoral' funds, redirected corporate taxes that implement a national strategic policy to promote high-quality research and development in a country's industries. Such funds, as one now functioning in Brazil, require close interaction of the indigenous academic community, private sector, and government in creating it, setting its priorities, and managing it. Decisions are all jointly made on the selection of strategic sectors, their respective shares of the fund's resources, the blend of basic and applied research, the required overall budget, and sources of support. (See Box 38.)

BOX 38 Brazil's sectoral funds

To promote high-quality research and development in Brazil's industrial sector, the national government has established a program of 'sectoral funds' in which a percentage of corporate taxes are targeted to funding specific research and development objectives. The sectoral-funds program serves four major government objectives:

- Stability of financial resources for medium- and long-term research and development;
- Transparency in funding decisions, merit review, and evaluation;
- Reduction of regional inequalities;
- Interaction between universities, research institutes, and companies.

The selection of strategic sectors, their respective shares of the funds' resources, the blend of basic and applied research, the required overall budget, and sources of support are all jointly decided upon by the indigenous academic community, private sector, and government. No new taxes are involved, just the redirection of already-established government levies. A comprehensive set of 14 funds has been established in the following areas: aeronautics, agriculture, biotechnology, energy, health, hydrology, informatics, infrastructure, minerals, petroleum, space sciences, telecommunications, transportation, and university-industry research.

www.mct.gov.br/Fontes/Fundos/Default.htm

BOX

BOX 39 Pakistan Telecommunication Company research funding

As part of an agreement with the Government of Pakistan, the Pakistan Telecommunication Company Limited, one of the country's largest commercial enterprises, devotes at least one percent of its annual gross revenue to science and technology capacity building in Pakistan. Because the primary aim of this fund is to achieve self-reliance and enhance the quality of life in Pakistan, funding is made available for technological and scientific research and development projects in selected fields that are relevant to the country. In addition to research and development, funds go to training and education programs. Proposals are evaluated by a committee of leading Pakistani scientists who rely on the time-tested mechanism of peer review for deciding which projects should receive these funds. Priority is generally given to scientific and engineering institutions with proven track records.

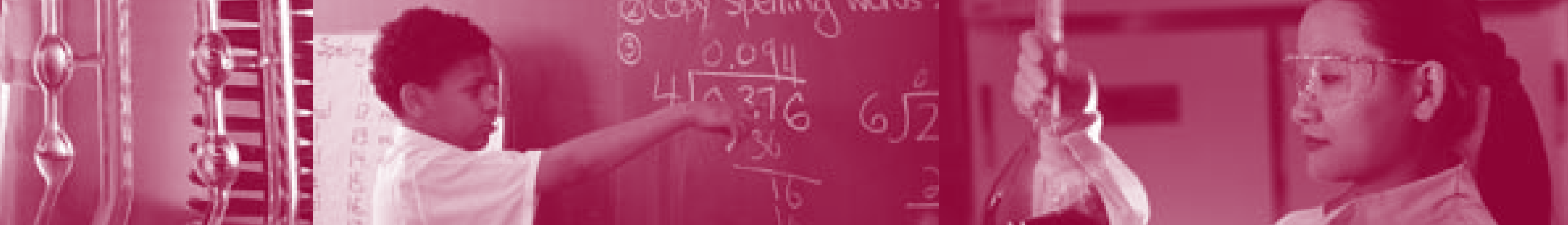
www.ptcl.com.pk/r&d.html

In the case of Brazil, a comprehensive set of 14 trust funds was established, with tripartite management by the academic community, government, and industry. Incentives for industry's participation include the applicability to local industry of the research and development that receives sectoral funding, as well as the fact that no new taxes are involved, just the redirection of already-established government levies. Politicians and policymakers tend to react well to this program, as it helps fulfill public policies to develop the countries' competencies in specific strategic areas. Moreover, because the allocation commitments made by government (usually the Ministry of Science and Technology or the equivalent) are long term, the 'playing field' can be taken as a given for sound corporate planning. In particular, the yearly resources do not have to be spent within the corresponding fiscal year (as in trust funds). Such predictability is a major draw for academic researchers as well.

Pakistan and India have reported successes with similar programs. (See Box 39 for a description of the Pakistan sectoral-funding program.)

Recommendations

- The option of national sectoral funding for research and development should be seriously considered by the public, private, and academic sectors of developing nations that aspire to significant S&T capacity.
- The management of each sectoral fund should be tripartite, with the participation of the academic community, government, and industry. A portion of each fund's resources should be used to support basic science, and another portion should support infrastructural needs.



6.2 Regional S&T networks should share responsibility for funding research

Beyond Australia, Canada, Japan, South Korea, the United States, and northern and western Europe, there are S&T-proficient countries amidst the many S&T-lagging ones in almost every region of the world. Regional networks, through which these proficient countries and their neighbors could together pursue world-class research and training activities on issues of mutual concern, should be created and supported in order to complement sectoral funds. The regional networks could in turn be involved in cooperative programs with S&T-advanced countries – which should, along with the international-donor and financing community, be willing to help fund these networks.

Recommendations

- The S&T-proficient countries should cooperate with S&T-lagging countries in world-class research and education through regional networks.
- Research nodes of the networks should be recognized centers of excellence in developing nations with a strong research base; this connection would help catalyze the strengthening of S&T capacities among their less-developed partners.
- The networks should stimulate interdisciplinary research and establish links with the member countries' private sectors.

BOX 40 **Consultative Group on International Agricultural Research**

Created in 1971, the Consultative Group on International Agricultural Research (CGIAR) is an association of 58 public and private members that supports a system of 16 agricultural research centers working in more than 100 countries and involving more than 8,500 scientists and scientific staff. Individual CGIAR members, which include industrialized countries, developing countries, foundations, and regional or international organizations, each support centers and programs of their choice. With a mission 'to contribute to food security and poverty eradication in developing countries,' CGIAR's agenda includes 'five major research thrusts':

- Increasing productivity,
- Protecting the environment,
- Preserving biodiversity,
- Improving policies,
- Strengthening national research.

All benefits of CGIAR research are kept within the public domain, and are available to all. In 2001, CGIAR members funded US$337 million for the 16 centers. The secretariat for CGIAR is sponsored by the World Bank.

www.cgiar.org

BOX

6.3 Global funding mechanisms should be strengthened for support of science and technology in developing nations

Of the many obstacles facing S&T institutions in the developing nations, two important problems could be alleviated with targeted global funds. These problems are:

- *Lack of autonomy*. An institution should be able to function without political interference and other bureaucratic impediments to the practice of science, engineering, and medicine.
- *Limited availability of funding*. Reliable financial support could help ensure autonomy and provide the necessary foreign-currency resources that enable local institutions to graduate to the international S&T arena (by participating in joint programs, attending conferences, or purchasing lab equipment).

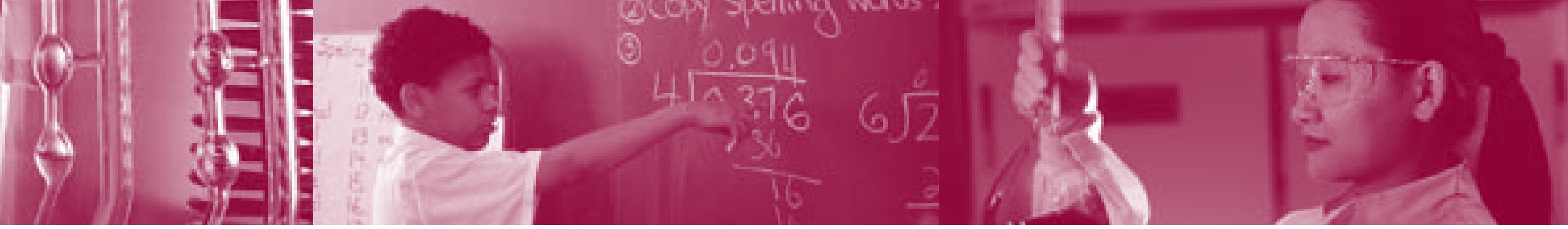
While the possibility exists for such funding through the targeted sectoral funds discussed above, it would require exceptionally committed governments and in some places may be insufficient for generating the needed foreign-currency resources.

To address that special set of issues, the Study Panel suggests that two global funds for S&T capacity building in developing nations – an institutional fund and a program fund – be set up in a consultative fashion, drawing on the experience of the Consultative Group for International Agricultural Research (CGIAR). (See Box 40.)

A *Global Institutional Fund* for developing nations would provide soft funding over a period of 5 to 10 years to some 20 centers of excellence of a national or regional character (operating by themselves or in developing-country networks). This funding would not be program-specific; it would be used instead to allow centers to promote the values of science, engineering, and medicine and create atmospheres in which the practice of high-quality research can flourish. Specifically, the money would help each center to develop its programs, cultivate its management, and build its long-term funding base.

Donors would meet in a consultative mode to review proposals resulting from an open call for competitive submissions, and they would select the centers according to the following criteria:

- Autonomy of the institution;
- Strength of its leadership, as assessed by peers;
- Quality of its management;
- Commitment to the values of science and engineering;
- General nature, extent, and relevance of its overall program of work;
- Potential to function as a hub and to network with other centers of excellence in the region;



- Ability to partner with S&T institutions in the industrialized nations for pursuing research projects of mutual interest.

These characteristics are similar to those identified for centers of excellence in section 4.1 above.

A *Global Program Fund* for developing nations would be organized as a competitive-grant system for creating new partnerships with advanced research institutes in S&T-advanced and S&T-proficient-countries. International referees would review the quality of the projects being proposed by various centers of excellence in developing nations. The Global Program Fund would require that proposals contain the following three basic features:

- A partnership between the center and an advanced research institute from either an S&T-advanced or S&T-proficient country,
- The advanced research institute's willingness to put a reasonable amount of its own resources into the project and to jointly perform a significant part of the research in the center of excellence in the developing nation
- The center's commitment to use some of its own resources in support of the project.

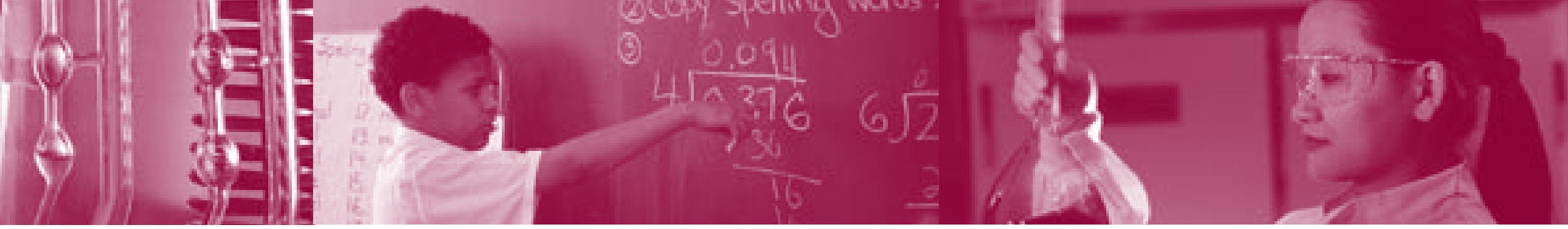
The purpose of these grants from the Global Program Fund would be to lubricate the mechanisms by which developing-country-based centers of excellence could productively interact with advanced research institutes in the S&T-advanced or S&T-proficient countries. They would facilitate bridge-building by creating incentives for developing-nation institutions to work with advanced research institutes and, importantly, vice versa. And they would increase the likelihood of productive capacity building in the developing nations. Individual researchers' skills and an institution's general competencies are best strengthened when scientists and engineers work together on specific projects.

Preference would be given to proposals that involve several local and regional institutions, but a bilateral proposal – one recipient center and one advanced research institute – would be perfectly acceptable, given the benefits of its one-on-one focus, together with the greater likelihood of meeting them.

The global funds would not have to be pooled but could remain distinct, though coordinated centrally. This would allow those donors with particular restrictions to honor them while still participating in the funding. For example, no impediments would result from regional banks' geographic limits on the recipient centers of excellence, or industrialized nations' nationality requirements for a participating advanced research institute (e.g., National Science Foundation grants are limited to U.S. recipients). And once a project was under way, donors could rely for quality control on internationally staffed reviews organized by an institution such as the InterAcademy Panel (IAP) or the InterAcademy Council (IAC).

Recommendations

- ►A Global Institutional Fund should be established to provide 'soft funding' over a period of 5 to 10 years to some 20 centers of excellence of a national or regional character (operating by themselves or in developing-country networks). This funding would not be program-specific; it would be used instead to allow centers to promote the values of science and engineering and to create an atmosphere in which the practice of high-quality research can flourish. Specifically, the money would help each center to develop its programs, cultivate its management, and build its long-term funding base. Donors would meet in a consultative mode to review proposals resulting from an open call for competitive submissions, and they would select the centers according to clearly established evaluation criteria.
- ►A Global Program Fund, creating new partnerships with advanced research institutes, should be established as a competitive grants system – for support of research groups in centers of excellence in developing nations – in which international referees would review the quality of the projects being proposed. Preference would be given to proposals that involve groups in several local and regional institutions. However, bilateral proposals – from one recipient center in cooperation with a research institute in an S&T-advanced or S&T-proficient country – would be perfectly acceptable, given the benefits of their one-on-one focus and the relative simplicity of their objectives (together with the greater likelihood of meeting them).
- ►Both funding programs should draw on the experience of the Consultative Group for International Agricultural Research (CGIAR). However, reflecting the need for updating policies that have worked for CGIAR in the past, the funding programs should differ from the CGIAR model in two important ways:
  - The centers receiving support from the institutional fund should not be international institutes but local and regional entities situated in the developing nations. Their numbers could change over time, and they would not necessarily be guaranteed complete coverage of all their needs.
  - The program funds may not be mingled with institutional funds, and the ensemble of recipients from each would often not be the same.



7. From ideas to impacts: coalitions for effective action

Having argued that indigenous science and technology (S&T) capacity is essential for a country's meaningful participation in the global economy, the Study Panel identified in this report several actions needed to achieve favorable outcomes. In particular, the five clusters of recommendations presented in Chapters 2 through 6 should be implemented. The question then becomes: Who will bring about the desired changes? Which 'principal actors' should play what roles? And what should each of them do so that the overall effect of their individual contributions – in building new programs and reforming existing programs – is potentially greater than the sum of the parts?

The Study Panel has identified the following twelve principal actors:

- S&T-proficient countries;
- S&T-lagging countries;
- S&T-advanced countries;
- United Nations agencies and regional intergovernmental organizations;
- Educational, training, and research institutions;
- National academies of sciences, engineering, and medicine;
- National, regional, and International S&T organizations;
- International development-assistance organizations;
- Foundations;
- Local, national, and international private sectors (for-profit entities);
- Nongovernmental organizations;
- The media.

Each of these players should undertake an individually tailored program of actions appropriate to its own role, based on the recommendations of this report. But action by any individual player will not suffice in the absence of coordination with the others. The building of coalitions, through which the various programs may be orchestrated and their impacts mutually reinforced, will be necessary for achieving the desirable synergistic and sustainable results.

In pursuit of that goal and to clarify a strategy for achieving it, the major recommendations of Chapters 2 through 6 are partitioned into three categories:

- *Urgent actions* for launching the process,
- *New initiatives* that could succeed where previous efforts have failed,
- *Well-established measures*.

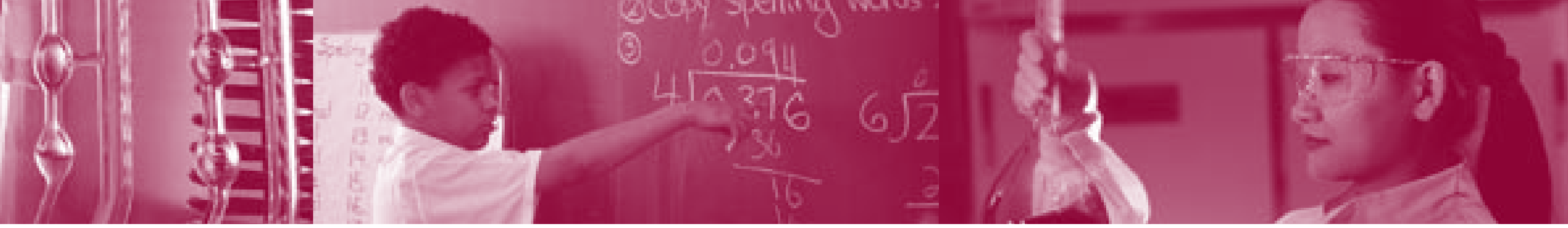
Needless to say, all of the programs mentioned in this report require funding. While calling for national governments to make significant commitments to supporting their own S&T capacity building (Section 2.2), the Study Panel notes that international development assistance should also play a part, and an increasingly important one at that. In many cases, this funding will come through existing channels, but innovative approaches will often be required as well; several such novel mechanisms have been highlighted in Chapter 6.

7.1 Urgent national and international actions can facilitate the strengthening of national science and technology

The four actions listed below are the initiating measures from which all else would follow; the other recommendations in this report – and the coalitions in different parts of the world that would implement them – will largely depend on the success of these urgent actions. As such, they should be undertaken immediately.

1. *Strengthen national academies of sciences, engineering, and medicine and the national S&T communities.* Academies are critical organizations that should be the leading voices of science and technology in each country, and they should reflect the positions of the nation's entire S&T community. These national academies, in fact, are deemed the key advocates for many of the actions recommended in this report. In cooperation with their nations' universities, disciplinary societies, and professional associations, they should actively work with government, the international community, and the media to expand S&T capacity and pursue its most productive and humane applications. They should be in close contact with their national leaders and key decisionmakers, and influencing them to act on these issues. In countries in which national academies do not exist, the InterAcademy Panel (IAP), Council of Academies of Engineering and Technological Sciences (CAETS), and InterAcademy Medical Panel (IAMP) should continue to promote their creation, meanwhile fortifying and engaging professional scientific and engineering associations (Section 4.4).

2. *Mobilize the international S&T community.* Scientists and engineers throughout the world, acting individually and through their organizations, should translate their wishes to fortify developing nations' S&T capacities into real actions that directly mobilize the local and regional talent. A special role is anticipated here for the Third World Academy of Sciences (TWAS) and the International Council for Science (ICSU), in addition to the direct involvement of the InterAcademy Panel (IAP) (Section 3.3).



3. *Raise the level of public awareness.* In general, given the reality that public pressure engages decisionmakers, the launching of coalitions pertaining to this report's recommendations should be accompanied by major public-awareness campaigns. These efforts at public education (and the general popularizing of science and technology) will critically depend on the degree of scientists' and engineers' cooperation with the media. And the dialogue, by definition, should go both ways: S&T practitioners should be open to learning about society's problems and people's concerns, for reasons of ethics and effectiveness. The science, engineering, and medical communities should also enlist the aid of professional S&T educators and media specialists in their campaigns (Section 2.3).

4. *Protect public goods and define the boundaries of the public/private interface.* This goal requires urgent attention simply because international negotiations on intellectual property rights currently under way could potentially compromise the ability of developing and especially S&T-lagging countries to build their capacity and join the global economy. Governments desperately need the input of the S&T community in these complicated negotiations (Chapter 5).

7.2 New initiatives can help promote indigenous S&T capacity

The following recommendations are new, or at least novel, to many S&T policymakers and to the public at large. The Study Panel believes that their implementation could well make the difference between success and failure in building indigenous S&T capacity around the globe.

1. *Attract, develop, and retain young scientists and engineers.* While on the face of it this recommendation may appear obvious, it is rarely addressed with enough seriousness, commitment, and breadth. Attraction of young talents to science and technology requires imaginative and compelling curricula. And retaining young talent depends not only on first-rate education and training (Section 3.1), but on programs for cultivating opportunity and recognition and reducing brain drain. This could be achieved by providing adequate compensation and working conditions, motivating them to return home to their native countries (if some of their training is abroad), and accommodating the special needs of women (Section 3.2). Once these new scientists and engineers are developed, they require access to the best regional facilities for continued training to deepen their knowledge and develop their skills (Section 3.3).

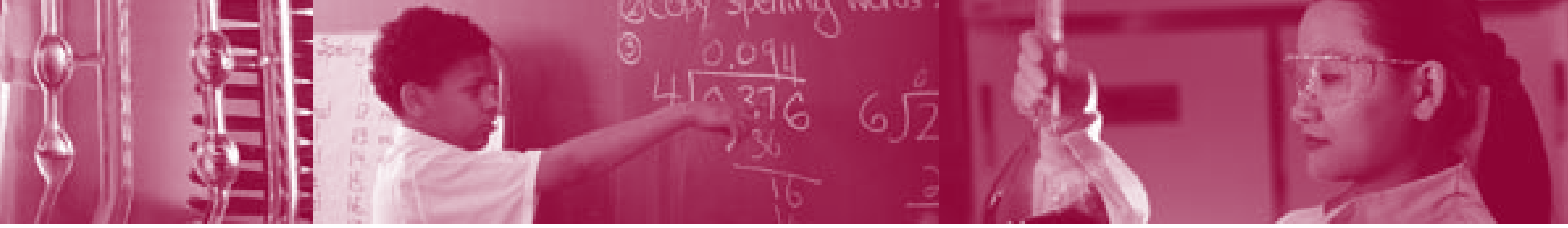
2. *Provide S&T education at all levels*. Scientific and technological outlooks, and their sense of discovery and accomplishment, need to be gained early so that a foundation is built for future S&T training throughout one's school years. A corollary is the need to develop special programs for ensuring quality S&T education for all students – not just for future scientists and engineers – to increase general S&T literacy and to propagate the values of open, honest science among the public at large (Section 3.1).

3. *Build centers of excellence*. This recommendation is a central premise of this report. The advancement of science and technology can only be assured with local centers of excellence, where the practice of science and technology and the training of a country's future generations of professionals can take place. Although a nation's infrastructure, links between its components, and connections to colleagues in other countries are important, it is a nation's centers of excellence – even if few in number – that truly drive a nation's effort to build capacity in science and technology (Section 4.1).

4. *Establish virtual networks of excellence (VNE)*. Another major premise of this report is the need for networks, each anchored in a physical center of excellence, that create virtual S&T complexes. Such Virtual networks of excellence are a fundamentally new means made possible by new communications technologies, by which links and consequent synergies between talented and compatible but geographically dispersed individuals and teams can be created to upgrade priority areas of research and development in particular countries and regions, and even worldwide (Section 4.3).

5. *Foster public-private partnerships that involve academia*. Increasingly, universities are establishing spin-off companies that have the right to patent and license the results of their advanced research, even though much of it originated in academic settings. This phenomenon potentially distorts the traditional function of the university, but if properly managed through partnerships that tap the strengths of each participant while safeguarding their basic interests, the risk can be minimized. Meanwhile, such partnerships offer important advantages for promoting cutting-edge research and directing its outcomes to the public good (Section 5.2).

6. *Strengthen links with expatriate scientists and engineers*. Given the reality that many of a developing nation's most talented individuals will opt to live and work in industrially advanced countries, it is important to at least build strong bridges to such persons. Significant efforts should be made



to secure for the native land some of the benefits of their education and experience, for example, through collaborative projects with local colleagues or students (Section 3.2).

7. *Create and maintain digital libraries.* The power of new information and communications technology should be harnessed, especially (but not exclusively) for the benefit of the S&T-lagging countries, by means of universal digital libraries that are readily accessible all over the world. Editors of S&T journals and books also need to do their part by facilitating online access to the literature, particularly for developing-nation S&T professionals and their institutions (Section 3.4).

8. *Build regional networks of collaboration.* Major collaborative frameworks among developing nations should be led by regions' S&T-proficient countries, which have a responsibility to help their S&T-developing and S&T-lagging neighbors (Section 4.3). These mechanisms require special funding efforts that not only address the basics – fellowships and joint research costs – but such mundane but frequently critical omissions as travel money (Section 6.2). Cooperation among developing nations in general is highly recommended. The Third World Academy of Sciences (TWAS) and other organizations, including the regional ones, should play an important role in achieving its realization.

9. *Devise novel funding mechanisms.* S&T consortia, such as CGIAR, which involve collaboration among industrialized and developing nations around particular issues, should all pay increased attention to S&T capacity building. But beyond the conventional methods, novel financing mechanisms to implement sectoral funds, global funds, and regional-cooperation grants – especially for covering interactions among developing nations – will also be needed (Section 6.3).

7.3 Some well-established measures deserve repeating

These well-known and generally accepted measures deserve inclusion here because they are indispensable parts of the mix and because – despite general declarations of acceptance and support – there has not been sufficient implementation. It is also important to keep pushing for the adoption of certain measures that have been regularly urged but insufficiently acted upon in the past.

1. *Develop national plans ('policy for S&T').* The need for a coherent national S&T strategy should be reaffirmed. Such a strategy, to be developed in consultation with a country's academies of sciences, engineering, and

medicine, should include clear statements of national priorities and attract funding commitments on the order of 1 to 1.5 percent of Gross Domestic Product (Section 2.1). Such strategies should be revised every four years or so.

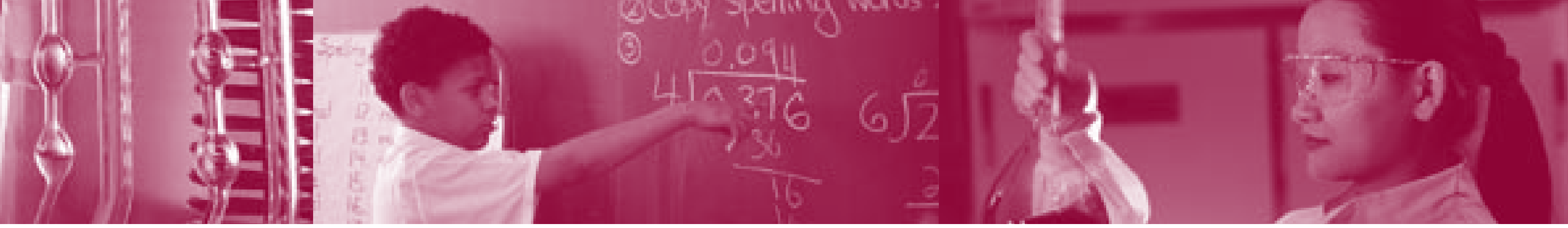
2. *Provide expert scientific inputs to policymaking ('S&T for policy')*. A nation's scientists and technologists, individually and through their academies and professional associations, universities, and research institutes, should be actively advising government decisionmakers on issues that have S&T-related components or implications (Section 2.2).

7.4 S&T-lagging countries urgently require regional and international collaboration

For some of the poorest and the smallest countries, the Study Panel emphasizes that S&T capacity building should be pursued on a *regional* basis – in collaboration with other countries – so that a critical mass of scientific capability can be achieved. These S&T-lagging countries merit direct attention through 'South-South' and 'North-South' cooperation and new commitments from the S&T-advanced and S&T-proficient countries. The agenda for S&T-lagging countries could include the following actions:

1. *Identify national S&T goals and priorities*. Each S&T-lagging country should develop a national S&T strategy that specifies priorities for research and development that address national needs in areas such as agriculture, health, industrial development, and the environment. The goals and priorities should be simple and clear. Strategies for implementation should focus on how collaboration with others will be undertaken. Special attention should be given to cooperation among developing nations. These strategies for science and technology should be developed in consultation with international experts and with the help of international organizations such as the World Bank, regional development banks, United Nations agencies, Third World Academy of Sciences (TWAS), InterAcademy Panel (IAP), and International Council for Science (ICSU).

2. *Mobilize international expertise for promoting national capabilities in science and technology*. Given the limited national capabilities in S&T-lagging countries, it will often make more sense to think in terms of forming national committees of eminent individuals to represent expertise in various fields (as opposed to building formal academies). Such committees should have extensive contacts with regional and international experts and be delegated to interact with the international bodies dealing with science and technology.



3. *Orient S&T capacity for achieving national goals.* Clearly, the focus of the poorest and smallest countries will be largely in the area of building up their national education systems at the primary and secondary level, with due attention to the gender dimension and to appropriate vocational training. However, emerging tertiary-level institutions should be helped early on to assume the multiple functions of the university. The existing S&T institutions should be regularly assessed through expert review and evaluation. Techniques for such procedures should include, as appropriate, peer-review teams, relevance-review panels, or benchmarking studies. Given the modest scientific capacity of S&T-lagging countries, their merit reviews should include appropriate experts from other nations. Such involvement of the global research community, possibly through a program of international cooperation among academies of science, engineering, and medicine, can make the merit-review processes in developing nations more effective, not just for particular programs, but more broadly.

4. *Participate in regional or international centers of excellence that address issues of national need.* Each S&T-lagging country should join with S&T-proficient countries to associate with those centers of excellence – whether of local, national, regional, or international status and whether actual or virtual institutes – that address the issues relevant to that country. Such networks, including Millennium Science Initiatives, can serve as the main nodes for those individuals or groups in the nation charged with enhancing S&T knowledge of national and regional importance. International institutions, such as the Third World Academy of Sciences (TWAS), InterAcademy Panel (IAP), and International Council for Science (ICSU), should be consulted to help in the formation and strengthening of nascent national and regional institutions. Governments of S&T-lagging countries should consider regional and multilateral cooperation and sharing of resources for implementing intellectual property protection, so that countries with limited technical resources do not have to duplicate effort, investment, and dedication of scarce talent.

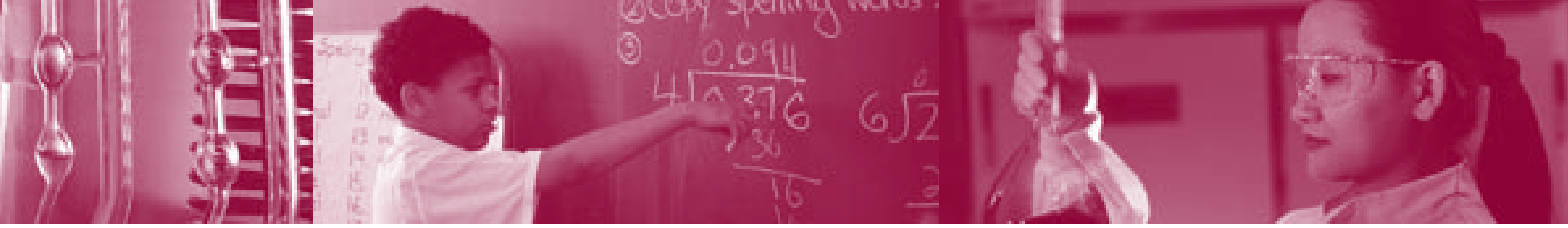
5. *Establish mechanisms for S&T advice to government.* Each nation requires trusted indigenous mechanisms for obtaining advice on scientific and technological questions related to public policies and programs. A committee of eminent individuals could provide an initial mechanism. Similarly, professional societies should be engaged; and informed and reliable counsel could also come from specially appointed committees of outside experts, cooperating with local scientists and engineers.

6. *Provide information on S&T resources and issues to the public.* Innovation is required for disseminating the results of research and turning them into new products and services that address local needs. Special attention should be given to the country's agricultural extension service and to health-information dissemination and public-education campaigns. A special effort – with international support – should be made to ensure that at least a few libraries in each nation can develop and maintain wide-bandwidth electronic gateways for accessing and sharing electronic S&T information resources among researchers, teachers, students, and the general public.

7. *Upgrade educational programs and institutions.* Beyond expansion and diversification of the national education system at the tertiary level, each S&T-lagging country should establish projects for modernizing elementary- and secondary-school education; these projects should emphasize inquiry-directed learning of principles and skills while highlighting the values of science. Each government should also focus special resources on providing high-quality training and support for S&T teachers, as these individuals will be especially critical for building future capacities.

8. *Join regional and international S&T training programs.* Governments of S&T-lagging countries should seek S&T collaboration with more advanced countries, especially the S&T-proficient countries, and with international organizations to design and obtain financial support for master's and doctoral programs. When feasible, university 'sandwich programs,' which provide for a portion of S&T training abroad, should be emphasized. Fellowships for graduate students should be preferentially awarded to nationals from lesser-developed nations. These fellowships should include re-entry grants that allow the returning fellows to obtain some basic resources that will permit them to carry out research work in the home laboratory and that will facilitate maintaining collaborative contacts with the centers where they received training.

9. *Increase S&T career opportunities within the country.* Governments of S&T-lagging countries should seriously consider providing, on a temporary basis, special working conditions for their best talents (formed at centers of excellence), including income supplements and adequate research support. These governments should also build ties with their expatriate scientists and engineers, especially those working in industrialized nations, who should be encouraged to participate in national scientific advisory panels and spend time in their country of origin to facilitate the creation of new scientific institutions and programs.



7.5 A global ‘implementation strategy’ can lead to new S&T initiatives

This report’s recommendations should not meet the fate of so many other efforts whose thoughtful recommendations garnered political declarations and lip service but little else. It is essential that this report lead to real action, that things really happen on the ground. To that end, the Study Panel proposes that the InterAcademy Council (IAC) – in consultation with other relevant international and national organizations – develop an ‘implementation strategy’ that identifies concrete actions for helping international, national, and local actors bring about reforms and introduce the necessary innovations.

The implementation strategy would include an action plan for the following:

1. *Monitoring the implementation of programs.* Experienced people should work with international, regional, and national entities – in the science and technology, academic, political, private-sector, and funding communities – to ensure that words are translated into deeds.

2. *Promoting action networks.* Many national and regional efforts to strengthen S&T capacity, including those organized and supported by various Scandinavian agencies, the European Community, Canada’s International Development Research Centre, U.S. Agency for International Development, the HIV/AIDS Global Fund, the World Bank, and Consultative Group for International Agricultural Research (CGIAR), already exist. The latent synergies between such efforts have not been fully realized. The implementation strategy would seek to bring together promising possibilities for coordination, with a view to producing more significant results.

3. *Establishing a clearinghouse for knowledge derived from new information and communications technologies.* . The use of information and communications technologies is essential for modern scientists and engineers, yet such technologies in most developing nations are inadequate. For that reason, many groups are either gathering information about the state of these technologies in those countries or trying to add to their information and communications capacity, though there is little coordination between such efforts. An implementation strategy should recommend such a coordination mechanism, while identifying gaps in access to information and communications technologies and keeping governments and funders informed of emerging ideas.

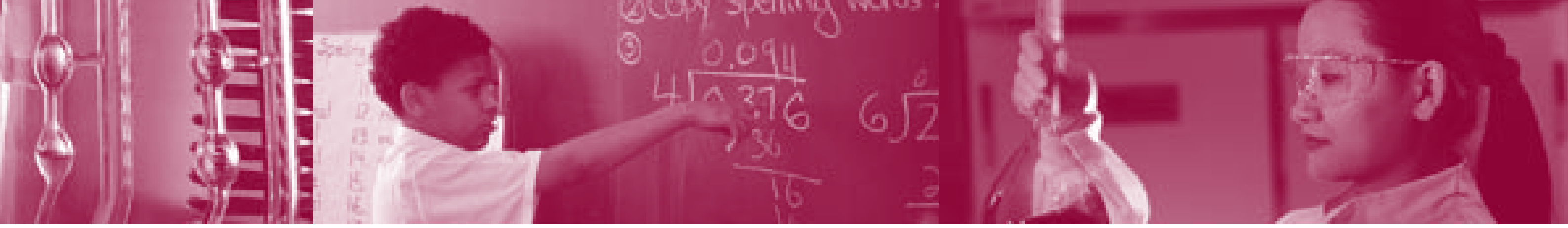
4. *Mining the most useful S&T data, and rendering it more accessible.* Good data about S&T in developing nations is scarce. The United Nations, the World Bank, and other excellent sources of information exist, but a coordinator needs to identify appropriate data within these institutions and distribute it to decisionmakers in easily usable form.

5. *Networking among academies.* National academies of sciences, engineering, and medicine are important for upholding the quality of S&T activity in a country, for guiding national policies based on science and technology, and for maintaining dialogue with other countries, often through their counterpart academies.

The implementation strategy should identify specific milestones to achieve, together with 'road maps' to help countries and S&T communities implement their programs. Such road maps, which could be coordinated through the InterAcademy Council (IAC), would be based on the following principles:

- Design or adopt a sound policy framework.
- Work with local scientific leaders to design relevant and achievable projects, in consultation with relevant government departments, potential funders, and groups such as professional associations and nongovernmental organizations.
- Design an objective mechanism for selecting and evaluating candidate projects.
- Begin to develop steady support through meetings with relevant government departments and other stakeholders.
- Identify a champion entity within government (such as a lead ministry); organize meetings of involved parties/stakeholders and the World Bank, the regional development banks, foundations, and such bilateral donor agencies in the European Union, Canada, Japan, Scandinavia, and the United States, among others.
- Work with the champion entity to place each project within a nation's budget and development plan.

The strategy should include a prospectus for creating a small, flexible, and agile 'implementation office' to translate words into action. Essential to the operation of such an implementation office will be the voluntary participation of national and regional academies. Even a small office could multiply its effect many times over if members of the academies are willing to carry out much of the actual implementation work. Similarly, participating academies could ensure access to governments, funding agencies, and aid groups with which the implementation office would have to interact in order to carry out its charge.



7.6 An international conference of financial donors can help develop new mechanisms for increasing S&T capacity in developing nations

Many of the recommendations in this report require new or improved procedures for funding science and technology in the developing nations. The international community of financial donors should develop such procedures.

A special kick-off conference of the international community of financial donors should be convened to review and refine the recommendations contained in this report. If they agree with the recommendations, a steering committee should be formed to develop the mechanisms needed for implementation. Multilateral institutions, national governments, foundations, the for-profit sector, and nongovernmental organizations should be represented at the conference. Some recommendations may advance faster than others, but it would be useful to quickly secure initial funding for the most attractive and least controversial among them. In that way, participants could start turning some of the recommendations into reality, thereby giving a boost to the whole endeavor.

The more advanced among the developing nations should participate in this conference and agree to play key roles in relevant projects that come to pass. The national governments of other developing nations and some of these nations' leading private-sector groups, for their part, should make commitments to support sectoral funds tailored to their nations' needs. Regional and national conferences designed to get the project moving should take place following the kick-off conference.

The international lenders (the World Bank and the regional development banks and funds), as well as bilateral donors and foundations, should declare their general willingness to provide funding for S&T capacity building in the developing world and, it is hoped, generally endorse the recommendations for sectoral funds, regional networks, and global funds.

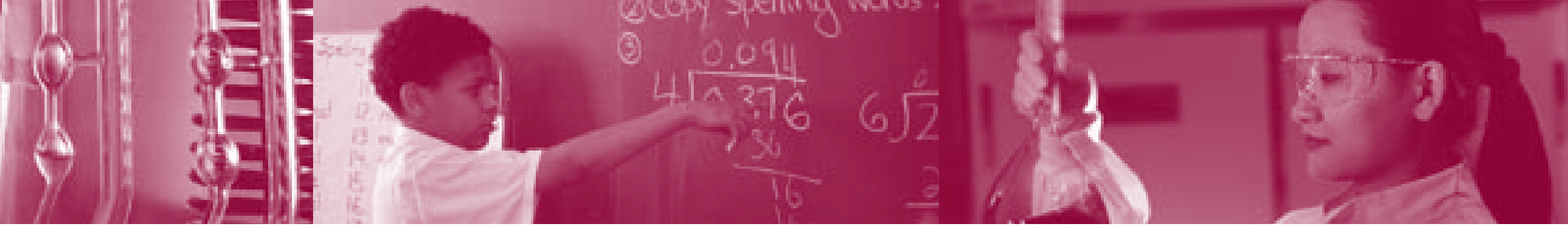
7.7 A better future is within our grasp

It is within our grasp to invent a better future for humanity. Current conditions are not frozen for all time. We can work to ensure that science and technology are harnessed to address the needs of all, rather than add to the luxury of a few. Science and technology can help reduce, rather than exacerbate, the already enormous gaps. The economic success of South Korea is an example showing that the current trends can indeed be reversed.

In that spirit, it is absolutely necessary for developing nations to strengthen their S&T capacity. And they should do so soon, through their own focused efforts with help from their friends. Given the currently rapid rate

of change in science and technology, there is no time to waste if the majority of humanity is not to suffer further marginalization.

We must, by our actions from this day forward, lay down the foundations for better tomorrows, when the benefits of science and technology will reach the traditionally detached, include the excluded, serve the unserved, and give hope to every human being on our planet that he or she too has a chance to live in dignity, comfort, health, and happiness. If we truly believe in our common humanity, we must aim for no less.



Notes

[1] National Research Council, *Cities Transformed: Demographic Change and Its Implications in the Developing World*, Washington, DC: National Academies Press, 2003 (accessible at www.nap.edu).

[2] United Nations Development Programme, 'Human Development Indicators,' *Human Development Report 2003,* UNDP, 2003(accessible at www.undp.org/hdr2003).

[3] In this report, national S&T capacities are categorized qualitatively as S&T advanced, S&T proficient, S&T developing, and S&T lagging. It should be clear that country groupings – industrialized nations vs. developing countries, or S&T-advanced vs. S&T-proficient vs. S&T-developing vs. S&T-lagging countries – are not absolute categories. Even if one were to say that the industrialized nations encompass both S&T-advanced and S&T-proficient countries and that the developing countries encompass S&T-developing and S&T-lagging countries, this would still not be enough. Some countries may be advanced in some aspects of agricultural technology, for example, but lagging in information and communications technology. Nevertheless, the countries concerned will recognize themselves and should be able to select from the report the recommendations that are most appropriate to their specific needs. For more information on national S&T classifications, see Christine Wagner, et al,. *Science and Technology Collaboration: Building Capacity in Developing Countries?* (Santa Monica, Calif.: RAND Corporation, 2001) (accessible at www.rand.org/publications/MR/MR1357.0/MR1357.0.pdf); and Robert Watson, Michael Crawford, and Sara Farley, 'Strategic Approaches to Science and Technology in Development,' World Bank Research Policy Working Paper Series, No. 3026. World Bank, Washington, D.C., 2003 (accessible at econ.worldbank.org/files/25709_wps3026.pdf).

[4] United Nations Development Programme, *Human Development Report 2003: Millennium Development Goals: A Compact Among Nations to End Poverty* (New York, NY: United Nations, 2003) (accessible at www.undp.org/hdr2003).

[5] United Nations Development Programme, *Human Development Report 2003: Millennium Development Goals: A Compact Among Nations to End Poverty* (New York, NY: United Nations, 2003) (accessible at www.undp.org/hdr2003).

[6] InterAcademy Panel on International Issues, 'Transition to Sustainability in the 21st Century: The Contribution of Science and Technology.' Conference of Academies, May 2000, Tokyo, Japan; IAP Secretariat, Trieste, Italy (accessible at www.interacademies.net/iap).

[7] See, for example, World Bank and UNESCO, *Higher Education in Developing Countries: Peril and Promise,* Final Report of the Task Force on Higher

Education and Society, Washington, D.C., 2000 (available at publications.worldbank.org/ecommerce); UNESCO, *Globalization and the Market in Higher Education: Quality, Accreditation, and Qualifications,* Paris, France: United Nations Educational, Scientific, and Cultural Organization, (available at upo.unesco.org); and UNESCO, *Universities and Globalization: Private Linkages, Public Trust*, Paris, France: United Nations Educational, Scientific, and Cultural Organization, 2003 (available at upo.unesco.org).

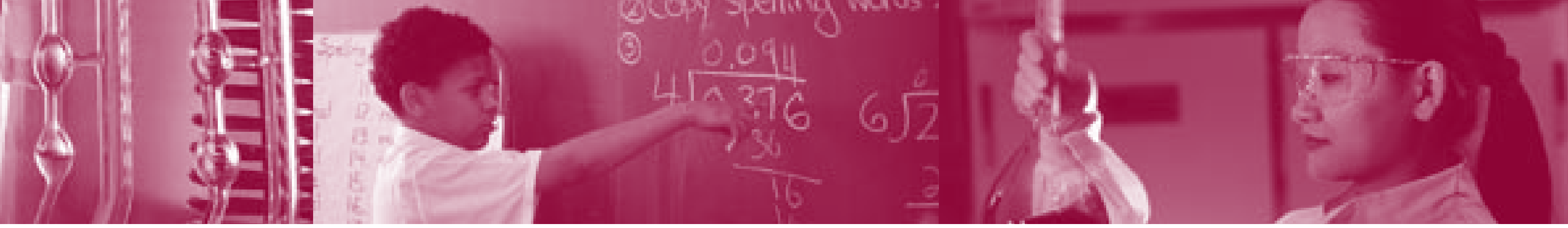
[8] R&D investments here include all expenditures within a country for basic, strategic, applied, and adaptive research, and development of new products and services – from all sources, including governmental and nongovernmental organizations and for-profit companies, for both nondefense and defense purposes.

[9] This question is replete with definitional and measurement complexities, but deserves to be addressed. For instance, the reporting numbers for research and development have been distorted for years by the conflation of defense and non-defense research and development. It is worthwhile to point out that, whether in the former Soviet Union or in North Korea today, massive spending on defense R&D did not immediately translate into a meaningful improvement of economic well-being for those countries' citizens, or even an increased level of international economic competitiveness for their industries. Shares of defense research and development in the national R&D enterprise have declined in most OECD countries since the end of the Cold War (with an enormous drop in Russia, accompanied by a drop of GDP as well). Between 1988 and 1998, spending on defense research and development in the United States went from 31 percent to 15 percent, in France from 21 percent to 7 percent, and in the United Kingdom from 17 percent to 12 percent. In light of this trend, some analysts believe, we can now assess research and development as a percent of GDP without major risk of distortion from the defense/nondefense element; see U.S. National Science Board, Science and Technology Indicators 2002, Washington, D.C., 2002, pp. 4-48 (accessible at www.nsf.gov/sbe/srs/seind02).

[10] U.S. National Science Board, *Science and Engineering Indicators 2002* (Arlington, Virginia: National Science Foundation, 2002), text table 4-13, pg. 4-47 (accessible at www.nsf.gov/sbe/srs/seind02); United Nations Development Programme, Human Development Report 2003 (New York, NY: UNDP, 2003)) (accessible at www.undp.org/hdr2003).

[11] The Commission of the European Communities has agreed to set a goal of R&D funding at 3 percent of EU GDP by 2010, of which two-thirds would be funded by the private sector; see Commission of the European Communities, 'Investing in Research, An Action Plan for Europe,' communications from the Commission, April 30, 2003; Brussels, Belgium, 2003 (accessible at http://europa.eu.int/eur-lex/en/com/cnc/2003/com2003_0226en02.pdf).

[12] U.S. National Science Board, *Science and Engineering Indicators 2002* (Arlington, Virginia: National Science Foundation, 2002), text table 4-13, pg. 4-47



(accessible at www.nsf.gov/sbe/srs/seind02); United Nations Development Programme, *Human Development Report 2003* (New York, NY: UNDP, 2003) (accessible at www.undp.org/hdr2003).

13 National Science Board, Science and Engineering Indicators 2002 (Arlington, VA: National Science Foundation, 2002) (accessible at www.nsf.gov/sbe/srs/seind02).

14 For more information, access www.uct.za/misc/iapo/ushepia/middle.htm.

15 National Science Board, *Science and Engineering Indicators 2002* (Arlington, VA: National Science Foundation, 2002) (accessible at www.nsf.gov/sbe/srs/seind02).

16 National Science Board, *Science and Engineering Indicators 2002* (Arlington, VA: National Science Foundation, 2002) (accessible at www.nsf.gov/sbe/srs/seind02).

17 Carl Dahlman and Karl Andersson, eds., *Korea and the Knowledge-Based Economy: Making the Transition*, Joint World Bank-OECD study (Washington, D.C.: World Bank Institute, The World Bank, 2000) (available at publications.worldbank.org/ecommerce).

18 National Research Council, *Patents in the Knowledge-Based Economy* (Washington, DC: National Academies Press, 2003) (accessible at www.nap.edu).

19 P. Troullier, et al, 'Drug Development for Neglected Diseases: A Deficient Market and a Public Health Policy Failure,' *The Lancet*, 359:2188-94, 2002.

20 TRIPS requires all World Trade Organization members to provide minimum standards of protection for a wide range of intellectual property rights, including copyrights, patents, trademarks, industrial designs, geographical indications, semiconductor topographies, and undisclosed information. In doing so, TRIPS incorporates provisions from many existing international intellectual property agreements, such as the Paris and Berne Conventions administered by the World Intellectual Property Organization. TRIPS, however, also introduces a number of new obligations, particularly in relation to geographical indications, patents, trade secrets, and measures governing how intellectual property rights should be enforced. See 'Integrating Intellectual Property Rights and Development Policy,' Commission on Intellectual Property Rights, London, 2002, (accessible at www.iprcommission.org).

21 TRIPS took effect on 1 January 1995. World Trade Organization (WTO) members considered to be industrialized nations were given one year to comply, while developing countries and transition economies were given until 1 January 2000 – although for developing countries an additional 5 years was provided before protection of new areas such as pharmaceuticals had to be introduced. Least-developed countries are expected to enact TRIPS by 2006, although the Doha Ministerial Declaration on the TRIPS Agreement and Public Health allowed them a further 10 years with regard to pharmaceutical products. See 'Integrating Intellectual Property Rights and Development Policy,' Commission on Intellectual Property Rights, London, 2002, (accessible at www.iprcommission.org).

Annex A: Endorsement InterAcademy Panel

Dr. Bruce Alberts, Co-Chair
Dr. Goverdhan Mehta, Co-Chair
InterAcademy Council
Het Trippenhuis
P.O. Box 19121
1000 GC Amsterdam
NETHERLANDS

Dear Dr. Alberts and Dr. Mehta:

We are pleased to inform you that the world's academies of sciences, brought together within the InterAcademy Panel (IAP), endorse the recommendations of the InterAcademy Council (IAC) report *Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology,* through a plenary resolution adopted by the IAP General Assembly in Mexico City on 4 December 2003.

Scientific and technological capabilities must become integral to all nations if humanity is to confront effectively the significant challenges of the 21st Century. The world faces rapidly increasing needs in areas such as energy and associated environmental challenges – global warming, atmospheric pollution, and degradation of land and oceans. New biological threats – in the form of new and old infectious diseases – can spread across the globe at the speed of a modern jet. Nearly 9 billion people must be fed without expanding land available for agriculture. Sustainable economic growth requires new knowledge and technologies. To meet these challenges, scientific and technical talent is required in all regions of the world to adapt and apply existing knowledge, to develop new knowledge and capabilities, and to provide expert advice and judgment.

Yet while several developing countries have recently made major improvements in scientific and technological capacity, most continue to lack the tools of science and technology, and lose their most talented individuals to the industrialized nations. Research expenditures per person in the industrialized nations are many times greater than in the developing nations.

To address the challenges ahead, each nation should have the following capacities:

- indigenous mechanisms for obtaining advice on scientific and technological questions related to public policies and programs;
- a science and technology strategy that specifies the national priorities for research and development and spells out national funding commitments, to be disbursed using a merit-based approach;

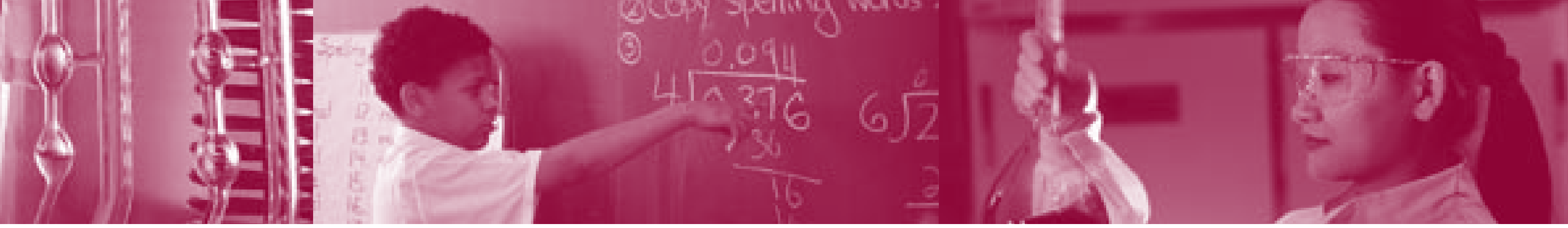
- human resources policies and programs for promoting science and technology, including high-quality education and training; developing, attracting, and retaining local scientific and technical talent; and encouraging participation in international scientific networks;
- centers of scientific and technological excellence to address issues of local importance and "virtual networks of excellence" - innovative groups that are located far apart but closely linked via the Internet and anchored in recognized research centers organized either nationally, regionally, or globally;
- partnerships and consortia among government, universities, and industry for addressing research and applications in areas of potential local benefit; and
- adequate financial resources for conducting education, research and development in areas of vital importance.

The world's academies of sciences commit themselves to achieving these scientific and technological capacities described above in our own countries and regions and to working with colleagues in other regions to build capacity worldwide. We are convinced that with the support of international authorities and organizations, the backing of governments, and direct help from scientists, engineers, and health professionals, a worldwide effort in this area can make major progress in the next two decades in effectively addressing the challenges facing humanity.

Sincerely yours,

Yves Quéré
Co-Chair
InterAcademy Panel

Chen Zhu
Co-Chair
InterAcademy Panel



Annex B: Agendas for major actors in building science and technology capacity

Introduction

To build worldwide science and technology (S&T) capacities, all major institutions should work together to:

1. Foster a global mobilization to create a better future for humanity;
2. Convene a kick-off conference to launch, review, refine, and initiate the implementation of the set of proposals presented in this report;
3. Convene regional and national conferences to review, refine, and initiate the implementation of the set of proposals presented in this report.

But each type of institutional actor will have different roles and responsibilities in this effort. The Study Panel has identified a set of twelve major 'actors' necessary to implement the needed reforms and new programs for increasing worldwide scientific capacity:

- S&T-proficient and S&T-developing countries;
- S&T-lagging countries;
- S&T-advanced countries;
- United Nations agencies and regional intergovernmental organizations;
- Educational, training, and research institutions;
- National academies of sciences, engineering, and medicine;
- National, regional, and international S&T organizations;
- International development-assistance organizations;
- Foundations;
- Local, national, and international private sectors (for-profit entities);
- Nongovernmental organizations;
- The media.

The recommendations of the previous chapters are re – organized here to reflect needed actions by each of these twelve sectors.

Agenda for S&T-proficient and S&T-developing countries

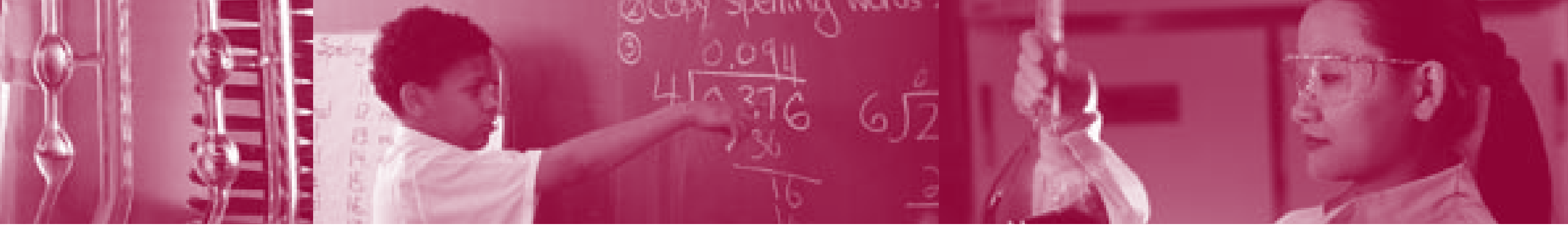
This category includes countries defined as: (1) S&T-proficient – with scientific and technological strength in several research areas and a growing S&T capacity in all aspects, including personnel, infrastructure, investment, institutions, and regulatory framework; and (2) S&T-developing – with scientific and technological strength in one or more research areas, but generally lacking important aspects of S&T capacity in personnel, infrastructure, investment, institutions, and regulatory framework.

1. Identify national science and technology goals and priorities

- The government of each S&T-proficient and S&T-developing country should develop a national S&T strategy that specifies priorities for research and development that address national needs in areas such as agriculture, health, industrial development, and the environment. This should involve high government officials at the federal level, including state and even municipal levels where appropriate, the national research councils, and technological and innovation agencies.
- Such strategies for science and technology should be developed by the national government in full consultation with the country's science, engineering, and medical academies, and other scientific organizations.
- National funding commitments for science and technology should rise to at least 1 percent – preferably 1.5 percent – of Gross Domestic Product, and should be disbursed using a merit-based approach.
- The option of national 'sectoral' funding for research and development – a portion of a nation's tax levies on for-profit corporations redirected into a special fund for financing the conduct of research in selected science and technology areas of economic interest to the nation – should be seriously considered by the public, private, and academic sectors of developing nations that aspire to significant S&T capacity. The management of each fund should be tripartite, with the participation of the academic community, government, and industry. A portion of each fund's resources should be used to support basic and applied sciences, and another portion should support infrastructural needs.

2. Assess strengths and weaknesses of current S&T capacity for achieving goals

- The effectiveness of national S&T institutions, including the following, should be reviewed:
  - *Autonomous centers of excellence* – research programs, within a university, a research institute, or operating independently, typically in one geographical location, and deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output;
  - *Strong universities* – tertiary educational institutions for educating and training new generations of S&T talent, performing research and development in areas of societal need, and providing an independent source of information on topics of importance to the nation;
  - *Virtual networks of excellence* – research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the internet and the World Wide Web, deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output;



– *Independent national or regional academies of sciences, engineering, and medicine* – merit-based autonomous institutions, in which peers elect new members in recognition of their distinguished and continuing professional achievements, elect their own officials, perform programs of independent work, and inform the general public and national decisionmakers on science and technology aspects of public policies.

- Existing S&T institutions should be assessed through expert review and evaluation. Techniques for such procedures should include, as appropriate, peer review teams, relevance-review panels, or benchmarking studies. Given the relatively modest scientific capacity of most developing nations, their merit reviews should ideally include appropriate experts from other nations. Such involvement of the global research community, possibly through a program of international cooperation among academies of science, engineering, and medicine, can make the merit review processes in developing nations more effective not just for particular programs but in general.

3. Establish a government-university-industry partnership for strengthening S&T capacity

- Governments, industries, universities, and research institutes should experiment with partnerships and consortia for addressing research areas of potential local benefit.
- Government in particular – both national and local – must play a central role in creating public-private research partnerships. National and local governments should ensure that individuals and organizations continue to have strong incentives and opportunities to capitalize on research. To this end, one of the new ideas to be considered is the implementation of a group of 'sectoral' funds involving the primary economic activities in each country, as described in Section 6.1 and Box 37.

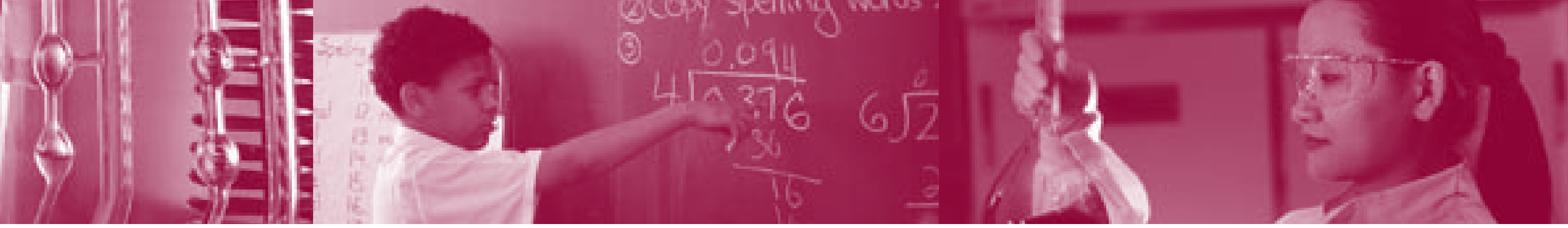
4. Create centers of excellence that address research issues of national need

- Centers of excellence – research programs, within a university, a research institute, or operating independently, typically located in one geographical location, and deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output – should be created, or seriously planned for the near future, in practically every S&T-proficient country. Such centers can serve as the main nodes for individuals or groups charged with enhancing S&T knowledge of national and even regional importance.
- These centers of excellence should have institutional autonomy, sustainable financial support, knowledgeable and capable leadership, international input, focused research agendas that include interdisciplinary

themes, applied research as well as basic research, technology transfer, peer review as a systemic element, merit-based hiring and promotion policies, and mechanisms for nurturing new generations of S&T talent. New scientific and technological research projects should be decided on the basis of input from expert review, with each project and program evaluated for both technical merit and its potential benefits to society.
- International funding sources for such centers of excellence – including international development banks, donor governments, philanthropic foundations, and for-profit corporations – should be identified and sought.
- Virtual networks of excellence (VNE) – research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the internet and the World Wide Web, deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output – should be created nationally, regionally, and globally. Emergent centers of excellence should be involved in the virtual networks of excellence.
- International institutions such as Third World Academy of Sciences (TWAS), InterAcademy Panel (IAP), and International Council for Science (ICSU) should be consulted to help in the formation and strengthening of nascent national and regional institutions. The participation of these international bodies will help new organizations to establish the requisite high standards and effective mechanisms of operation.
- Where bilateral scientific and technological agreements with S&T-advanced countries are established, provision should be made for the participation of qualified S&T personnel from neighboring S&T-lagging countries.

5. Upgrade ongoing research programs that address issues of national need

- Where relevant research institutions already exist, they should be reinforced or, if necessary, reformed. When reform is indicated, changes should be systemwide and carried out in ways that make the best use of scarce resources (including the local talent). Where there is much talent but the system is bureaucratized, it is crucial that reform includes the following:
  – Focus on themes, not institutions (i.e., abolish institutional entitlement);
  – Build up a small but select number of centers of excellence;
  – Build up a few nodes (around individuals) of top expertise;
  – Open up the research system to competitive grants;
  – Protect public-goods research;
  – Address essential long-term issues.



- All existing research programs and centers of excellence can similarly benefit from periodic expert review and evaluation. Techniques for such procedures should include, as appropriate, peer review teams, relevance -review panels, or benchmarking studies. Given the relatively modest scientific capacity of most developing nations, their merit reviews should ideally include appropriate experts from other nations. Such involvement of the global research community, possibly through a program of international cooperation among academies of science, engineering, and medicine, can make the merit review processes in developing nations more effective not just for particular programs but in general.

6. Establish mechanisms for S&T advice to government

- Establish trusted indigenous mechanisms for obtaining advice on scientific and technological questions related to public policies and programs. Informed and reliable counsel could come from specially appointed committees of experts, standing multidisciplinary advisory bodies, or independent institutions such as merit-based academies of science, engineering and medicine.
- Develop the means to assess and manage the benefits and risks associated with the development, production, or use of new technologies, such as those deriving from biotechnology. Government should therefore ensure that indigenous S&T capacities are in place not only to enable effective adoption of a new technology but also to help implement public-health, human-safety, and environmental guidelines or regulations associated with potential side-effects of the new technology. The possibility of long-term effects should be kept in mind when setting up such systems, which should remain fully adaptable to rapid advances in scientific and engineering knowledge.
- Coordinate technology assessments with other nations to permit the sharing of experience and the standardization of some types of risk assessment.

7. Provide information on S&T resources and issues to the public

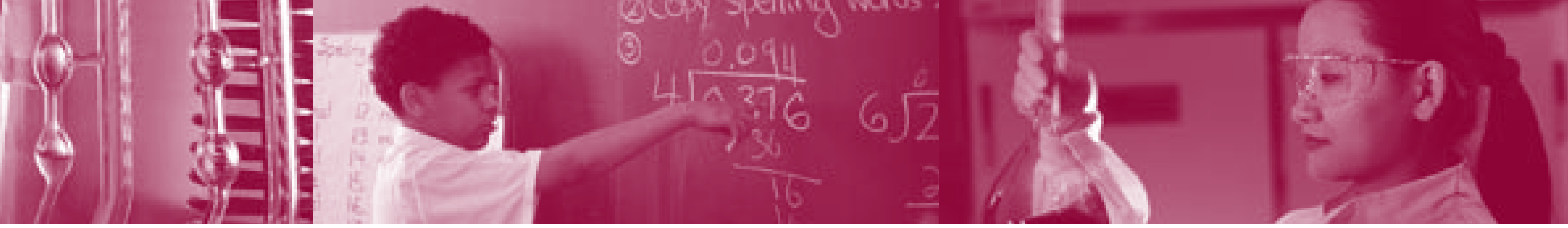
- Encourage innovation in disseminating the results of publicly funded research and in turning them into new products and services that address local needs. Such efforts could include:
  - Consultative services, provided by national or regional research institutions, in areas such as agriculture, water and land management, housing, and health;
  - Cooperative partnerships between local citizens and research institutions for sharing up-to-date information of local relevance;
  - Empowerment of social entrepreneurs for supplying products and services significantly below market prices to people in need;
  - 'Information kiosks,' either publicly funded or for-profit, to help distribute useful information obtained from the Internet.

8. Upgrade educational programs and institutions

- Each nation should establish an S&T-education policy that not only addresses its own particular national needs but instills an awareness of global responsibilities (e.g., environmental). Consequent national projects should particularly aim to modernize such education at the elementary- and secondary-school levels (ages 5-18); and they should emphasize inquiry-directed learning of principles and skills while highlighting the values of science.
- Each government should focus resources on providing high-quality training for science/technology teachers. This will involve special efforts at all tertiary-education institutions, including research universities.

9. For S&T-proficient countries, share responsibilities for regional and international S&T training and research programs

- The S&T-proficient countries should cooperate with S&T-lagging countries in sponsoring world-class research and education through regional networks, which should have the following characteristics:
  - Research nodes of the networks should be recognized centers of excellence in developing nations with a strong research base; this connection would help catalyze the strengthening of S&T capacities among their less-developed partners.
  - The networks should stimulate interdisciplinary research and establish links with the member countries' private sectors.
- Centers of excellence in S&T-proficient countries should provide scholarships and research facilities, including the use of their own laboratories, to help achieve international cooperation with and among other developing nations. Where bilateral or multinational research and training programs are established with S&T-advanced nations, such programs should facilitate the participation of qualified S&T personnel from neighboring S&T-developing and S&T-lagging countries. These programs should also take into account the often-critical need for travel money.
- Regional S&T cooperation with other developing nations that leads to doctoral degrees, together with postdoctoral programs, should be promoted in national or regional centers of excellence, especially those that are in S&T-proficient countries among the developing ones. Fellowships for graduate students (master's and doctoral degrees) should be preferentially awarded to nationals from S&T-developing and S&T-lagging countries. These fellowships should include re-entry grants that allow the returning fellows to obtain some basic materials and instrumentation that will permit them to carry out research in the home laboratory and that will facilitate maintaining collaborative contacts with the research centers where they received training.



- The training of new scientists and engineers should be aided by networks that have already been established by practicing professionals in diverse specialties. These networks should be given enduring support by academic, governmental, intergovernmental, and private organizations.
- National governments and international organizations should provide the financial support and design the institutional framework to establish 'sandwich programs' that provide for a portion of educational training abroad.
- A number of programs and fellowships to support S&T capacity-building activities have previously been established by some countries and by organizations such as UNESCO, Third World Academy of Sciences (TWAS), International Centre for Theoretical Physics (ICTP), and International Council of Science (ICSU). A database of all such activities should be created and posted on a Website available to all scientists and engineers, even those working in the remotest regions of the world.

10. Increase S&T career opportunities within the country

- To spur locally needed S&T activities, governments of developing nations should seriously consider providing, on a temporary basis, special working conditions for their best talents (whether formed at centers of excellence abroad or at home), including income supplements and adequate research support, with a primary focus on young scientists and engineers.
- Governments of developing nations, in collaboration with their national S&T communities, should be encouraged to build ties with their expatriate scientists and engineers, especially those who are working in industrialized nations.
- Incentives should be established to help encourage companies, especially in the developing world, to create in-house research units and hire S&T talent. Local governments could give them tax rebates or national recognition for building their human-resources capacity (say, through internship programs and contracted research). More broadly, a national strategic policy to promote research and development in a country's industries, including the provision of 'sectoral' funds, should be established. For their part, governments of developing nations should provide re-entry grants to encourage young scientists trained in the industrialized world to return home.

11. Develop digital S&T information sources

- Libraries should maintain electronic gateways for the sharing of digital information among researchers, teachers, and learners.
- Major hubs in the developing world should be organized for sharing digital information with research institutions in the industrialized world.

This will facilitate access to some materials (in video format, for example) that require wide bandwidth not necessarily available everywhere. It will also serve the eminently sensible goal of backing up original material.

12. Develop effective policies for intellectual property rights

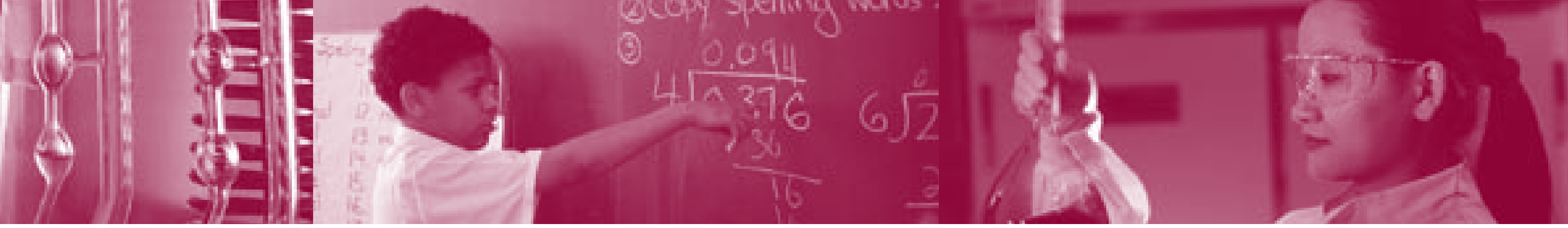
- Every country should develop a clear legal framework regarding the activities of the private sector in S&T capacity building, and it should be compatible with the national S&T policy while providing incentives for real technology transfer.
- Governments of S&T-proficient as well as S&T-developing countries should focus on licensing issues, accept strong intellectual property rights for new medicines, negotiate special agreements on generics for basic pharmaceutical products, promote local industry through partnerships with foreign companies, and amend their current legislation for intellectual property rights to emphasize the genuine invention of useful technologies while putting less focus on the protection of minor or intermediate technologies and processes. Such focus often discourages further research and development.
- Governments of S&T-developing nations should consider regional and multilateral cooperation and sharing of resources for implementing intellectual property protection, so that countries with limited technical resources do not have to duplicate effort, investment, and dedication of scarce talent.

Agenda for S&T-lagging countries

This category includes countries with little scientific or technological research strengths and no discernable overall S&T capacity in personnel, infrastructure, investment, institutions, and regulatory framework.

1. Identify national science and technology goals and priorities

- The government of each S&T-lagging country should develop a national S&T strategy that specifies priorities for research and development that address national needs in areas such as agriculture, health, industrial development, and the environment. This should involve high government officials at the federal level, including state and even municipal levels where appropriate.
- Such strategies for science and technology should be developed in consultation with international experts and the help of international organizations such as the World Bank, regional development banks, United Nations agencies, InterAcademy Panel (IAP), Third World Academy of Sciences (TWAS), and International Council of Science (ICSU).
- Each country should have, at a minimum, the following types of institutions, and the national S&T strategy should include goals for developing them:



– *Autonomous centers of excellence* – research programs, within a university, a research institute, or operating independently, typically in one geographical location, and deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output;
– *Strong universities* – tertiary educational institutions for educating and training new generations of S&T talent, performing research and development in areas of societal need, and providing an independent source of information on topics of importance to the nation;
– *Virtual networks of excellence* – research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the internet and the World Wide Web, deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output;
– *Independent national or regional academies of science, engineering, and medicine* – merit-based autonomous institutions, in which peers elect new members in recognition of their distinguished and continuing professional achievements, elect their own officials, perform programs of independent work, and inform the general public and national decisionmakers on science and technology aspects of public policies.

- National funding commitments for science and technology should rise to at least 1 percent – preferably 1.5 percent – of Gross Domestic Product, and should be disbursed using a merit-based approach.

2. Mobilize international expertise for promoting national capabilities in science and technology

- Given the limited national capabilities in S&T-lagging countries, it will often make more sense to think in terms of forming national committees of eminent individuals to represent expertise in various fields (as opposed to building formal academies). Such a committee could have extensive contacts with regional and international experts and be delegated to interact with the international bodies dealing with science and technology.

3. Orient S&T capacity for achieving national goals

- Clearly, the focus of the poorest and smallest countries will be largely in the area of building up their national education systems at the primary and secondary level, with due attention to the gender dimension and to appropriate vocational training. However, emerging tertiary-level institutions should be helped early on to assume the multiple functions of the university.
- Existing S&T institutions should be regularly assessed through expert review and evaluation. Techniques for such procedures should include, as appropriate, peer review teams, relevance review panels, or benchmarking studies.

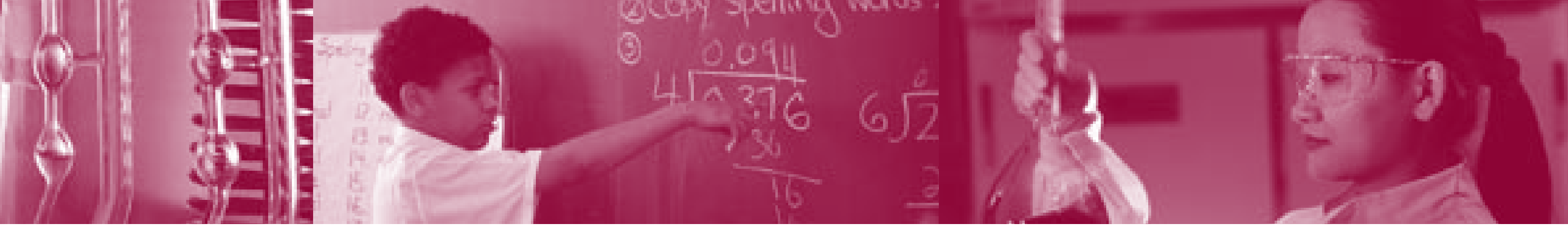
- Given the modest scientific capacity of S&T-lagging countries, their merit reviews should include appropriate experts from other nations. Such involvement of the global research community, possibly through a program of international cooperation among academies of science, engineering, and medicine, can make the merit review processes in developing nations more effective, not just for particular programs, but more broadly.

4. Participate in regional or international centers of excellence that address issues of national need

- Each S&T-lagging country should join with S&T-proficient countries to associate with those centers of excellence – research programs managed by a university, an advanced research institute, or operating independently, typically in one geographical location, and deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output – whether of local, national, regional, or international status, that address the issues of critical importance to that nation.
- These should include virtual networks of excellence (VNE) – research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the internet and the World Wide Web, deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output.
- The option of national 'sectoral' funding for research and development – corporate national tax set-asides for the conduct of research in areas of economic interest to the nation – should be seriously considered by the public, private, and academic sectors of developing nations that aspire to significant S&T capacity. The management of such funds should be tripartite, with the participation of the academic community, government, and industry. A portion of each fund's resources should be used to support basic and applied sciences, and another portion should support infrastructural needs.
- International institutions such as Third World Academy of Sciences (TWAS), InterAcademy Panel (IAP), and International Council of Science (ICSU) should be consulted to help in the formation and strengthening of nascent national and regional institutions. The participation of these international bodies will help the new national organizations establish the requisite high standards and effective mechanisms of operation, including periodic international reviews of the research institutions and programs.

5. Establish mechanisms for S&T advice to government

- S&T-lagging countries should establish trusted indigenous mechanisms for obtaining advice on scientific and technological questions related to public policies and programs. Informed and reliable counsel could also come from specially appointed committees of outside experts.



- In cooperation with other nations, S&T-lagging countries should achieve the means to assess and manage the benefits and risks associated with the development, production, or use of new technologies, such as those deriving from biotechnology. Government should ensure that indigenous S&T capacities are in place not only to enable effective adoption of a new technology but also to help implement public-health, human-safety, and environmental guidelines or regulations associated with potential side-effects of the new technology. Coordination of technology assessments with other nations will permit the sharing of experience and the standardization of some types of risk assessment.

6. Provide information on S&T resources and issues to the public

- S&T-lagging countries should encourage innovation in disseminating the results of research and in turning them into new products and services that address local needs. Such efforts could include:
  - Consultative services, provided by expert consultants, in areas such as agriculture, water and land management, housing, and health;
  - Cooperative partnerships between local citizens and research institutions for sharing up-to-date information of local relevance;
  - Empowerment of social entrepreneurs for supplying products and services significantly below market prices to people in need;
  - Information kiosks,' either publicly funded or for-profit, to help distribute useful information obtained from the Internet, with translation into the local language.
- Libraries should develop or maintain wide-bandwidth electronic gateways for accessing and sharing electronic S&T-information resources among researchers, teachers, students, and the general public.

7. Upgrade educational programs and institutions

- Each nation should establish an S&T-education policy that addresses its own particular national needs. National projects should aim to modernize such education at the elementary- and secondary-school levels (ages 5-18); and they should emphasize inquiry-directed learning of principles and skills while highlighting the values of science.
- Each government should focus resources on providing high-quality training and support for science/technology teachers. This will involve special efforts at all tertiary-education institutions, including research universities.

8. Join regional and international S&T training and research programs

- National governments should work with more scientifically advanced nations and with international organizations to design and obtain financial support for 'sandwich programs' that provide for a portion of S&T training abroad.

- Regional cooperation in science and technology should include training that leads to doctoral degrees and postdoctoral work experience. Regional centers of excellence should provide scholarships and research facilities, including the use of their own laboratories, for educational training in science and technology.
- The training of new scientists and engineers should be aided by networks that have already been established by practicing professionals in diverse specialties. These networks should be given enduring support by academic, governmental, intergovernmental, and private organizations in more advanced nations.

9. Increase S&T career opportunities within the country

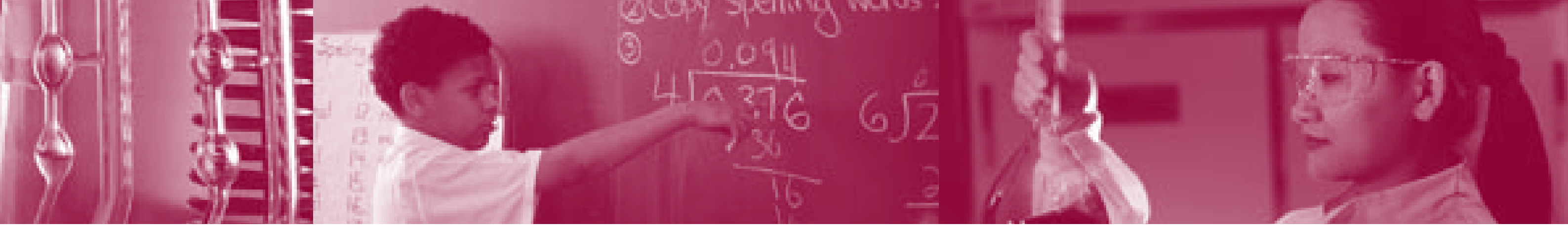
- To spur locally needed S&T activities, governments of developing nations should seriously consider providing, on a temporary basis, special working conditions for their best talents (whether formed at centers of excellence abroad or at home), including income supplements and adequate research support.
- Governments of developing nations, in collaboration with their national S&T communities, should be encouraged to build ties with their expatriate scientists and engineers, especially those who are working in industrialized nations. These scientists and engineers should be encouraged to participate in national scientific advisory panels and to facilitate the creation of new scientific institutions and programs.

Agenda for S&T-advanced countries

This category includes countries with scientific and technological strength in most research areas and a substantial S&T enterprise in personnel, infrastructure, investment, institutions, and regulatory framework.

1. Support research and development efforts in developing nations that address local and global needs

- S&T-advanced countries should provide financial support and collaboration for creating centers of excellence in developing nations – whether of local, national, regional, or international status. In particular, bilateral scientific and technological agreements between S&T-advanced and S&T-proficient countries should provide for participation by scientists and engineers from neighboring S&T-developing and S&T-lagging countries.
- International financial support and participation are required for creation of virtual networks of excellence (VNE) – research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the internet and the World Wide Web, deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output.



- Research in developing nations should be supported through the following programs:
  – Research grants for poor-country diseases,
  – Support for global health initiatives,
  – Tax incentives to major companies for working in these countries and for supporting automatic licensing and other initiatives.
- S&T-advanced countries should participate in a conference of international community of donors to review the concept of a global fund for science and, if they agree to it, help form a steering group to develop the funding mechanisms necessary for implementation. They should also play leadership roles in related projects that come to pass.

2. Share information and experiences in benefit/risk assessments of new technologies

- Share experience and information with scientifically developing nations about the benefits and risks of new technologies and the standardization of risk assessments. Each nation involved in the development, production, or use of new technologies, such as those deriving from biotechnology, should have the means for assessing and managing their benefits and risks. Governments should therefore ensure that expert scientific advice is available from regional or international sources not only to assure effective adoption of new technologies but to facilitate implementation of public health, human safety, and environmental guidelines or regulations associated with their potential side-effects.

3. Support the education and training of S&T professionals in developing nations

- International support for technology professionals and doctoral programs in the developing nations' best universities should be increased by offering long-term fellowships with adequate stipends to deserving young people from the industrialized nations who wish to do their training or at least spend some time in centers of excellence there. As an integral part of this experience, visiting professors from industrialized nations should help raise the level of courses and participate in exams and thesis defenses.

- Special fellowships or grants should be supported – by governments or private institutions – that are designed to provide adequate research support and income supplements to outstanding young scientists from the industrialized nations who work in developing nations for a period of time. Such special treatment may require local institutional flexibility, but it would be amply justified by the fundamental benefit of stimulating and retaining the local talent.

Agenda for United Nations agencies and regional intergovernmental organizations

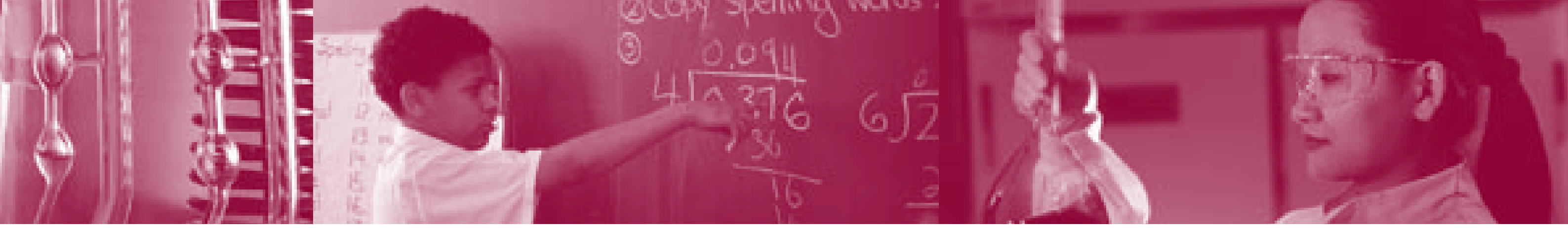
1. Help developing nations to identify national S&T goals and priorities

- United Nations agencies and regional intergovernmental organizations should help developing nations to create national S&T strategies through financial support and expert consultation. The objective should be the setting of national priorities for research and development that address national needs in areas such as agriculture, health, industrial development, and the environment.

2. Support research and development efforts in developing nations that address local and global needs

- International financial support and collaboration is required for creating centers of excellence in developing nations – whether of local, national, regional, or international status.
- International financial support and participation is required for creation of new virtual networks of excellence (VNE) – research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the internet and the World Wide Web, deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output – at national, regional, and global levels.
- United Nations agencies and regional intergovernmental organizations should support and help finance the creation of two global funds – an institutional fund and a program fund – that would provide international financial support to research programs of merit in developing nations.
- United Nations agencies and regional intergovernmental organizations should participate in a conference of international community of donors to review the concept of a global fund for science and, if they agree to it, help form a steering group to develop the funding mechanisms necessary for implementation. They should also play leadership roles in related projects that come to pass.

- Each nation involved in the development, production, or use of new technologies, such as those deriving from biotechnology, should have the means for assessing and managing their benefits and risks. Government should therefore ensure that expert scientific advice is available from regional or international sources not only to assure effective adoption of new technologies but to facilitate implementation of public health, human safety, and environmental guidelines or regulations associated with their potential side-effects.



3. Help developing nations to upgrade their educational institutions and programs

- These agencies and organizations should help each developing nation to establish a country – specific science – education policy that not only caters to national needs but instills an awareness of global responsibilities. Consequent national projects should particularly aim to modernize science education at the elementary- and secondary-school levels (ages 5-18); and they should emphasize inquiry-directed learning of scientific principles and skills while highlighting the values of science. Whether students go on to scientific careers or not, all should leave school with a good general understanding of science and its role in society.
- These agencies and organizations should help each government to focus resources on providing high-quality training for science and technology teachers. This will involve special efforts at all tertiary-education institutions, including research universities.
- These agencies and organizations should support government awards of special fellowships or grants, designed to provide adequate research and income supplements, to outstanding young scientists who work in developing nations for a period of time. Such special treatment may require local institutional flexibility, but it would be amply justified by the fundamental benefit of stimulating and retaining the local talent.

4. Help developing nations to provide information on S&T resources and issues to the public

- Funding should be provided for innovation in disseminating the results of new knowledge and technologies and in turning them into new products and services that address local needs. Such efforts could include:
  - Consultative services, provided by national or regional research institutions, in areas such as agriculture, water and land management, housing, and health;
  - Cooperative partnerships between local citizens and research institutions for sharing up-to-date information of local relevance;
  - Empowerment of social entrepreneurs for supplying products and services significantly below market prices to people in need;
  - 'Information kiosks,' either publicly funded or for-profit, to help distribute useful information obtained from the Internet.

5. Facilitate regional and international S&T research and training programs

- International organizations should offer financial support and help design the institutional framework to establish 'sandwich programs' that provide for a portion of S&T training abroad.

- Regional cooperation in S&T training that leads to doctoral degrees, together with postdoctoral programs, should be promoted in national or regional centers of excellence, especially those that are in S&T-proficient countries among the developing ones. In particular, such centers of excellence should provide scholarships and research facilities, including the use of their own laboratories, to help achieve international cooperation with and among developing nations. They should also take into account the often-critical need for travel money.
- The training of new scientists and engineers should be aided by networks that have already been established by practicing professionals in diverse specialties. These networks should be given enduring support by academic, governmental, intergovernmental, and private organizations.
- A number of programs and fellowships to support S&T capacity-building activities have previously been established by some countries and by organizations such as UNESCO, Third World Academy of Sciences (TWAS), International Centre for Theoretical Physics (ICTP), and International Council of Science (ICSU). A database of all such activities should be created and posted on a Website available to all scientists and engineers, even those working in the remotest regions of the world.

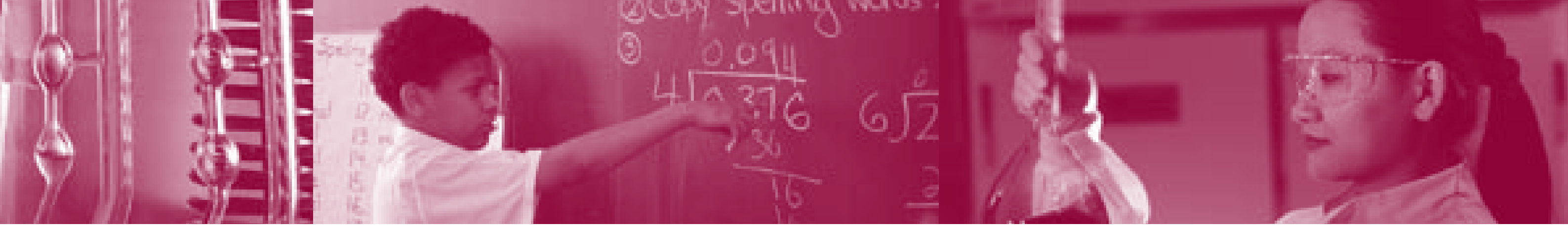
6. Support the development of digital S&T information sources

- These agencies and organizations should provide funding and expert support for libraries to maintain electronic gateways for the sharing of digital information among researchers, teachers, and learners.
- Major hubs in the developing world should be organized for sharing digital information with research institutions in the industrialized world. This will facilitate access to some materials (in video format, for example) that require wide bandwidth not necessarily available everywhere. It will also serve the eminently sensible goal of backing up original material.

Agenda for educational, training, and research institutions

1. Participate in national efforts to identify national S&T goals and priorities

- Educational, training, and research institutions in developing nations should be active participants in efforts of national and local governments to plan the development of national capabilities in science and technology.



2. Assess strengths and weaknesses of universities and research institutions for achieving national S&T goals

- Educational, training, and research institutions should undergo external reviews of their personnel, curricular, and research programs. Given the relatively modest scientific capacity of most developing nations, their merit reviews should ideally include appropriate experts from other nations. Such involvement of the global research community, possibly through a program of international cooperation among academies of science, engineering, and medicine, can make the merit review processes in developing nations more effective, not just for particular programs, but in general.

3. Establish a partnership with government and industry for strengthening S&T capacity

- Governments, industries, universities, and research institutes should experiment with partnerships and consortia for addressing research areas of potential local benefit.
- Public-private partnerships should be created with industry. Increasingly, universities are establishing spin-off companies that have the right to patent and license the results of their advanced research, even though much of it originated in academic settings. This phenomenon potentially distorts the traditional function of the university, but if properly managed through partnerships that tap the strengths of each participant while safeguarding their basic interests, the risk can be minimized. Meanwhile, such partnerships offer important advantages for promoting cutting-edge research and directing its outcomes to the public good.

4. Create centers of excellence that address issues of national need

- Centers of excellence – whether of local, national, regional, or international status – should be created, or seriously planned for the near future, in practically every university in order for S&T capacity to grow. Such centers can serve as the main nodes for individuals or groups charged with enhancing S&T knowledge of national and even regional importance.
- The centers should have institutional autonomy, sustainable financial support, knowledgeable and capable leadership, international input, focused research agendas that include interdisciplinary themes, applied research as well as basic research, technology transfer, peer review as a systemic element, merit-based hiring and promotion policies, and mechanisms for nurturing new generations of S&T talent.
- Universities and research institutes should affiliate with those centers of excellence – whether of local, national, regional, or international status – that address the issues of critical importance to that nation. These should include virtual networks of excellence (VNE)-innovative

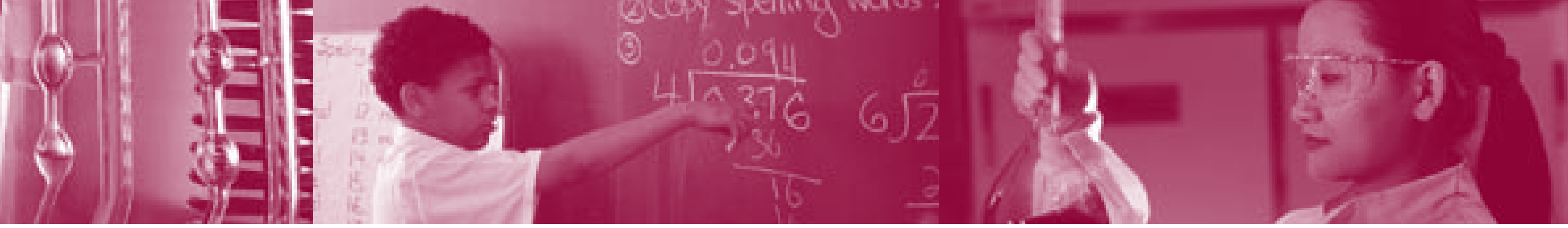
groups that are located far apart but closely linked via the Internet and anchored in recognized research centers, created nationally, regionally, and globally. Such networks can serve as the main nodes for those individuals or groups in the nation charged with enhancing S&T knowledge of national and regional importance.

5. Upgrade ongoing research programs that address issues of national need

- All existing research programs and centers of excellence can benefit from periodic expert review and evaluation. Techniques for such procedures should include, as appropriate, peer review teams, relevance -review panels, or benchmarking studies.
- Where such institutions already exist, they should be reinforced or, if necessary, reformed. When reform is indicated, changes should be systemwide and carried out in ways that make the best use of scarce resources (including the local talent). Where there is much talent but the system is bureaucratized, it is crucial that reform includes the following:
  - Focus on themes, not institutions (i.e., abolish institutional entitlement);
  - Build up a small but select number of centers of excellence;
  - Build up a few nodes (around groups) of top expertise with institutional support;
  - Open up the research system to competitive grants;
  - Protect public-goods research;
  - Address essential long-term national or strategic issues.
- New scientific and technological research projects should be decided on the basis of input from expert review, with each project and program evaluated for both technical merit and its potential benefits to society.

6. Upgrade educational programs and institutions

- Higher education in developing nations should be strengthened with public funds (supplemented with private funds if available) to offer greater opportunities for tertiary education and S&T-training to young people, ranging from 'community colleges' (as they are called in the U.S.) to top-class research-based universities.
- Universities should have increased autonomy while systematically seeking to strengthen their ties with regional and international institutions and networks; such links can significantly increase the effectiveness of the universities' S&T efforts.
- Research universities should make strong commitments to excellence and the promotion of the values of science in their activities, incorporating unbiased merit review into all of their decisions on people, programs, and resources; and they should also increase their interaction with society at large.



- Systems of higher education in developing nations should be reformed, giving special attention to university governance, balancing autonomy with national purpose, and moving toward institutional pluralism in the education and training system.
- All universities in developing nations should strengthen their undergraduate and graduate-degree programs in science and technology and offer fellowships to the best students.
- Universities in the industrialized nations should support S&T professionals and doctoral programs in the developing nations' best universities by offering long-term fellowships with adequate stipends to deserving young people who wish to do their training in centers of excellence there. Visiting professors from foreign countries should help raise the quality level of courses and research, and participate in exams and thesis defenses.
- All educational, training, and research institutions should focus resources on providing high-quality training for science and technology teachers.

7. Sponsor and participate in regional and international S&T training programs

- Universities in developing nations should explore regional cooperation in S&T training that leads to doctoral degrees, together with postdoctoral programs, should be promoted in national or regional centers of excellence, especially those that are in S&T-proficient countries among the developing ones. In particular, such centers of excellence should provide scholarships and research facilities, including the use of their own laboratories, to help achieve international cooperation with and among developing nations. These programs should take into account the often-critical need for travel money.
- S&T-advanced nations should create programs that establish short-term adjunct-faculty/research positions at some of their universities and laboratories for scientists and engineers from developing nations.

8. Provide information on S&T resources and issues to the public

- Educational, training, and research institutions should encourage innovation in disseminating the results of research and in turning them into new products and services that address national or local needs. Such efforts should include consultative services, provided by national, state or city research institutions, in areas such as agriculture, water and land management, housing, and health.
- Universities in developing nations should develop and maintain libraries with wide-bandwidth, electronic gateways for accessing and sharing electronic S&T information resources among researchers, teachers, students, and the general public.

Agenda for national academies of sciences, engineering, and medicine

This category includes merit-based autonomous institutions, in which peers elect new members in recognition of their distinguished and continuing professional achievements, elect their own officials, perform programs of independent work, and inform the general public and national decision-makers on science and technology aspects of public policies.

1. Participate in national efforts to identify national S&T goals and priorities

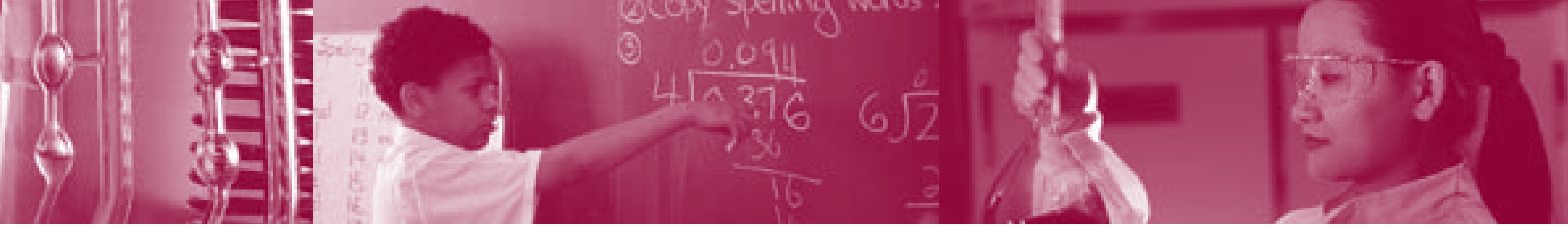
- Academies should help the national government to develop a national science and technology strategy that specifies priorities for research and development that address national needs in areas such as agriculture, health, industrial development, and the environment.
- It is essential that the academies actively participate in national and international debates to make the voices of science and technology heard on a broad range of issues.
- The national academies should become more actively involved in bringing together the private and public sectors; and they should work across sectoral and national boundaries to help promote collaboration between the industrialized and developing nations, as well as among the developing nations. Scientists and engineers can play especially productive roles here in articulating creative proposals for different countries and sectors.

2. Help the government to assess strengths and weaknesses of national capacities for achieving national S&T goals

- Academies should help in the performance of reviews by national research organizations of their personnel, curricular, and research programs. Given the relatively modest scientific capacity of most developing nations, their merit reviews should ideally include appropriate experts from other nations. Such involvement of the global research community, possibly through a program of international cooperation among academies of sciences, engineering, and medicine, can make the merit review processes in developing nations more effective, and not just for particular programs but in general.

3. Provide S&T advice to government

- Academies should develop robust and dependable mechanisms to provide advice to governments on scientific and technological questions related to public policies and programs.



4. Encourage new centers of excellence that address issues of national need

- Academies should help facilitate the future planning for and creation of centers of excellence – whether of local, national, regional, or international status. Such centers can serve as the main nodes for individuals or groups charged with enhancing S&T knowledge of national and even regional importance.
- Academies should encourage centers of excellence to have institutional autonomy, sustainable financial support, knowledgeable and capable leadership, international input, focused research agendas that include interdisciplinary themes, applied research as well as basic research, technology transfer, peer review as a systemic element, merit-based hiring and promotion policies, and mechanisms for nurturing new generations of S&T talent.

5. Promote the upgrading of ongoing research programs that address issues of national need

- Academies should participate in the evaluation of all existing research programs and centers of excellence. Techniques for such procedures should include, as appropriate, peer review teams, relevance -review panels, or benchmarking studies.
- New scientific and technological research projects should be decided on the basis of input from expert review, with each project and program evaluated for both technical merit and its potential benefits to society.

6. Promote the upgrading of educational programs and institutions

- Science and engineering academies and other S&T organizations should also be involved in teacher training and the production of materials needed for students' S&T education. Scientists should be encouraged to visit schools at all levels to support teachers and give well-designed presentations to promote science to the young. The InterAcademy Panel (IAP) and many national academies are already engaged in promoting programs that connect scientists to teachers, school systems, and curricular change, and the results of their experiences should be widely shared and disseminated.

7. Provide information on S&T issues of importance to the public

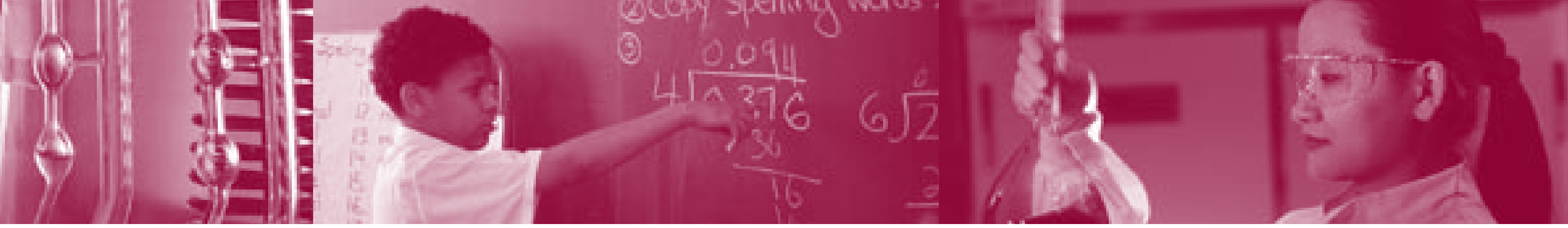
- Academies should disseminate the results of research relevant to national needs and the implications of new scientific and technological knowledge for effective public policies.

Agenda for national, regional, and international S&T organizations

Included in this category are S&T unions and professional societies, as well as the InterAcademy Panel (IAP), Third World Academy of Sciences (TWAS), Council of Academies of Engineering and Technological Sciences (CAETS), InterAcademy Medical Panel (IAMP), and International Council for Science (ICSU) with its affiliated National Members, International Scientific Unions, and Scientific Associates.

1. Facilitate the effectiveness of research programs in developing nations

- These organizations should promote the creation of centers of excellence – whether of local, national, regional, or international status – in each developing nation. For the S&T capacity of these countries to grow, the centers should have institutional autonomy; sustainable financial support; knowledgeable and capable leadership; international input (including collaboration with international institutions); a focused research agenda that includes interdisciplinary themes, applied research as well as basic research; and technology transfer; peer review as a systemic element; merit-based hiring and promotion policies; and mechanisms for nurturing new generations of scientific talent.
- These international scientific institutions should be encouraged to help in the formation and strengthening of nascent national and regional entities. The participation of these international bodies in reviewing plans of research or operation of the nascent entities will help them establish the requisite standards and effective mechanisms of operation.
- Encourage the creation of virtual networks of excellence (VNE) – research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the internet and the World Wide Web, deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output – at national, regional, and global levels.
- Virtual institutes-research programs undertaken by research personnel located in different geographical locations, communicating and collaborating primarily via new technologies such as the Internet and the World Wide Web – should be created. And they should be coordinated by researchers of exceptional scientific profile who are responsible for their scientific efforts and administration, and they should be housed at host institutions that provide adequate resources, both human and material. In the case of multi-institutional teams, other entities should also guarantee effective support for the project's participants in their purview.
- These international scientific institutions should participate in partnerships and consortia for addressing research areas of potential local



benefit. They should ensure that public-private research relationships do not impair the core mission and values of public research institutions.
- These international scientific institutions should work across sectoral and national boundaries to help promote collaboration between research programs in the industrialized and developing nations, as well as among the developing nations. Scientists can play an especially productive role in articulating the imaginative proposals needed in different sectors.

2. Participate in providing scientific advice to developing-nation governments on scientific questions related to public policies and programs

- These international scientific institutions should provide informed and reliable counsel to national governments on issues involving science and technology.
- These international scientific institutions should actively participate in governmental efforts to assess and manage benefits and risks of new technologies and actively advise governments in assuring not only effective adoption of a new technology but facilitating implementation of public-health, human-safety, and environmental guidelines or regulations associated with its potential side-effects.
- These international scientific institutions should encourage coordination of national advisory mechanisms between nations, as in the sharing of experience and the standardization of some types of risk assessment.
- These international scientific institutions should encourage innovation and experimentation in disseminating the results of publicly funded research and in turning them into new products and services that address local needs.
- The scientific community should pay serious attention to the news media and participate more fully in public debates and discussions. In such interactions, scientists should make an effort to explain scientific issues in nontechnical language.

3. Help developing nations to upgrade their educational institutions and programs

- International scientific organizations should encourage the scientific community to participate as resources for providing high-quality training for science teachers. This will involve special efforts at all tertiary-education institutions, including research universities.
- International scientific organizations Support programs for technology professionals and doctoral programs in the developing nations' best universities by offering long-term fellowships, with adequate stipends, to deserving young people who wish to do their training or at least spend some time in centers of excellence there. As an integral part of this expe-

rience, visiting professors from industrialized nations should help raise the level of courses and participate in exams and thesis defenses.

- International scientific organizations should strengthen undergraduate-degree programs in science and technology, and enrollment in these programs should be stimulated through fellowships awarded to the best students.
- International scientific organizations should encourage science academies and other scientific organizations to collaborate on activities such as teacher training and the production of materials needed for students' science education.
- International scientific organizations should participate in doctoral-fellowship programs for foreign students, and then maintain the relationships, through scientific cooperation, after the students return home. One such mechanism for cooperation would be the availability of some of the scientifically proficient country's laboratories for collaborative research with scientists from other nations in the region.
- International scientific organizations should provide information about sponsored fellowships and programs that support S&T capacity-building activities, as people seeking such opportunities may not be aware of them. Therefore a database of all such programs should be created and posted on a Website so that it is available even to scientists working in the remotest parts of the world.

Agenda for international development-assistance organizations

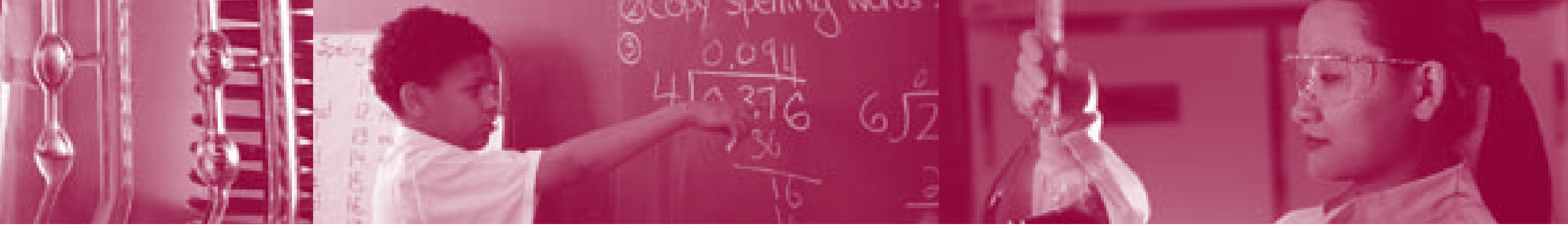
Included in the category are organizations such as the World Bank, regional development banks, and United Nations Development Programme

1. Help developing nations to identify national S&T goals and priorities

- Through financial support and expert consultation, development-assistance organizations should help developing nations to create national S&T strategies. The objective should be the setting of national priorities for research and development efforts that address national needs in areas such as agriculture, health, industrial development, and the environment.

2. Support research and development efforts in developing nations that address local and global needs

- International financial support and collaboration is required for creating centers of excellence-research programs, within a university, a research institute, or operating independently, typically located in one geographical location, and deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output – whether of local, national, regional, or international status.



- International financial support and participation is required for creation of new virtual networks of excellence (VNE) – research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the internet and the World Wide Web, deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output – nationally, regionally, and globally.
- Health research in developing nations should be supported through research grants for poor-country diseases and support for global health initiatives.
- Development-assistance organizations should support and help finance the creation of two global funds – an institutional fund and a program fund – that would provide international funding to research programs of merit in developing nations.
- Development-assistance organizations should participate in a conference of the international community of donors to review the concept of global funds for science and, if they agree to it, help form a steering group to develop the funding mechanisms necessary for implementation. They should also play leadership roles in related projects that come to pass.

3. Help developing nations to upgrade their educational institutions and programs

- Development-assistance organizations should help each developing nation to establish a country – specific science – education policy that not only caters to national needs but instills an awareness of global responsibilities (e.g., environmental). Consequent national projects should particularly aim to modernize science education at the elementary- and secondary-school levels (ages 5-18); and they should emphasize inquiry-directed learning of scientific principles and skills while highlighting the values of science. Whether students go on to scientific careers or not, all should leave school with a good general understanding of science and its role in society.
- Development-assistance organizations should help each government to focus resources on providing high-quality training for science teachers. This will involve special efforts at all tertiary-education institutions, including research universities.
- Development-assistance organizations should support government awards of special fellowships or grants, designed to provide adequate research support and income supplements, to outstanding young scientists who work in developing nations for a period of time. Such special treatment may require local institutional flexibility, but it would be amply justified by the fundamental benefit of stimulating and retaining the local talent.

4. Help provide information on S&T resources and issues to the public

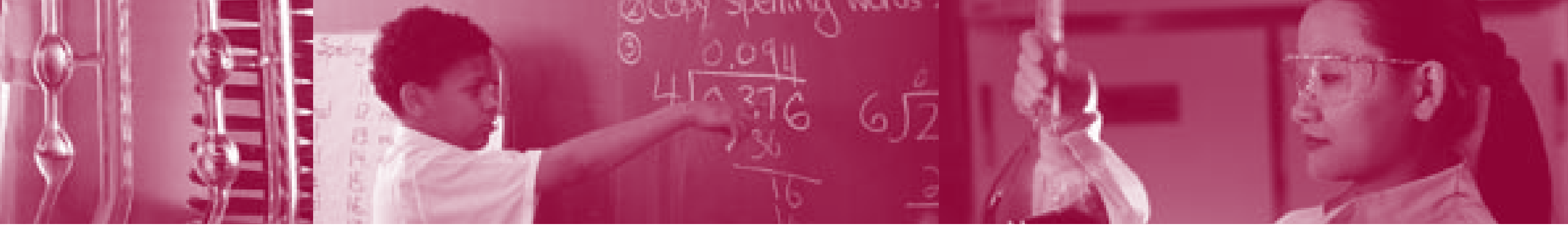
- Funding should be provided for innovation in disseminating the results of new knowledge and technologies and in turning them into new products and services that address local needs. Such efforts could include:
  - Consultative services, provided by national or regional research institutions, in areas such as agriculture, water and land management, housing, and health;
  - Cooperative partnerships between local citizens and research institutions for sharing up-to-date information of local relevance;
  - Empowerment of social entrepreneurs for supplying products and services significantly below market prices to people in need;
  - 'Information kiosks,' either publicly funded or for-profit, to help distribute useful information obtained from the Internet.

5. Help promote public-private partnerships

- Development-assistance organizations should promote imaginative partnerships between the public and private sectors that bring the benefits of scientific discoveries and technological innovations to all of the world's people. Such partnerships can invigorate education, conduct research of mutual interest, and capitalize on the results of the research for the benefit of society.
- Development-assistance organizations should provide assistance to help stimulate long-term public and private sector investments in effective local 'knowledge – based infrastructure' – the entire system of national private entrepreneurship, human resources, investment, and exploration of the advancing frontiers of S&T knowledge.

6. Facilitate regional and international S&T training programs

- International organizations should offer financial support and help design the institutional framework to establish 'sandwich programs' that provide for a portion of S&T training abroad.
- Regional cooperation in science and technology training that leads to doctoral degrees, together with postdoctoral programs, should be promoted in national or regional centers of excellence, especially those that are in S&T-proficient countries among the developing ones. In particular, such centers of excellence should provide scholarships and research facilities, including the use of their own laboratories, to help achieve international cooperation with and among developing nations. They should also take into account the often-critical need for travel money.
- The training of new scientists and engineers should be aided by networks that have already been established by practicing professionals in diverse specialties. These networks should be given enduring support by academic, governmental, intergovernmental, and private organizations.



- A number of programs and fellowships to support S&T capacity-building activities have previously been established by some countries and by organizations such as UNESCO, Third World Academy of Sciences (TWAS), International Centre for Theoretical Physics (ICTP), and International Council of Science (ICSU). A database of all such activities should be created and posted on a Website available to all scientists and engineers, even those working in the remotest regions of the world.

7. Support the development of digital S&T information sources

- International development-assistance organizations should provide funding and expert support for libraries to maintain electronic gateways for the sharing of digital information among researchers, teachers, and learners.
- Major hubs in the developing world should be organized for sharing digital information with research institutions in the industrialized world. This will facilitate access to some materials (in video format, for example) that require wide bandwidth not necessarily available everywhere. It will also serve the eminently sensible goal of backing up original material.

Agenda for foundations

1. Support research and development efforts in developing nations that address local and global needs

- International financial support and collaboration are required for creating centers of excellence – research programs, within a university, a research institute, or operating independently, typically located in one geographical location, and deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output – whether of local, national, regional, or international status.
- Foundations should financially support the creation of new virtual networks of excellence (VNE) – research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the internet and the World Wide Web, deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output – nationally, regionally, and globally.
- Research in developing nations should be supported through research grants for poor-country diseases and support for global health initiatives.
- Foundations should support and help finance the creation of two global funds – an institutional fund and a program fund – that would provide international funding to research programs of merit in developing nations.
- Foundations should participate in a conference of the international community of donors to review and refine the concept of global funds for

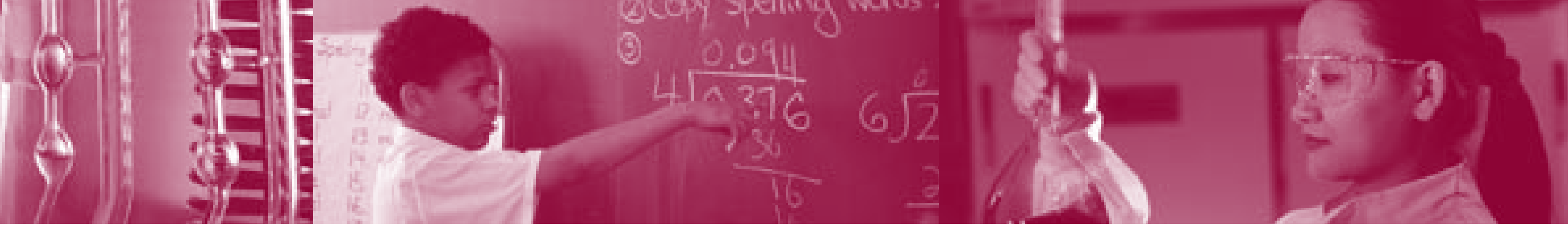
science and, if they agree to it, help form a steering group to develop the funding mechanisms necessary for implementation. They should also play leadership roles in related projects that come to pass.

2. Help developing nations to upgrade their educational institutions and programs

- Foundations should help each developing nation to establish a country – specific science – education policy that not only caters to national needs but instills an awareness of global responsibilities (e.g., environmental). Consequent national projects should particularly aim to modernize science education at the elementary- and secondary-school levels (ages 5-18); and they should emphasize inquiry-directed learning of scientific principles and skills while highlighting the values of science. Whether students go on to scientific careers or not, all should leave school with a good general understanding of science and its role in society.
- Foundations should help each government to focus resources on providing high-quality training for science and technology teachers. This will involve special efforts at all tertiary-education institutions, including research universities.
- Foundations should support government awards of special fellowships or grants, designed to provide adequate research support and income supplements, to outstanding young scientists who work in developing nations for a period of time. Such special treatment may require local institutional flexibility, but it would be amply justified by the fundamental benefit of stimulating and retaining the local talent. For their part, governments of developing nations should provide re-entry grants to encourage young scientists trained in the industrialized world to return home.

3. Help developing nations to provide information on S&T resources and issues to the public

- Funding should be provided for innovation in disseminating the results of new knowledge and technologies and in turning them into new products and services that address local needs. Such efforts could include:
  - Consultative services, provided by national or regional research institutions, in areas such as agriculture, water and land management, housing, and health;
  - Cooperative partnerships between local citizens and research institutions for sharing up-to-date information of local relevance;
  - Empowerment of social entrepreneurs for supplying products and services significantly below market prices to people in need;
  - 'Information kiosks,' either publicly funded or for-profit, to help distribute useful information obtained from the Internet.



4. Facilitate regional and international S&T training programs

- Foundations should offer financial support and help design the institutional framework to establish ‘sandwich programs’ that provide for a portion of S&T training abroad.
- Foundations should support innovative regional cooperation in S&T training that leads to doctoral degrees, together with postdoctoral programs. The training should be promoted in national or regional centers of excellence, especially those that are in S&T-proficient countries among the developing ones. In particular, such centers of excellence should provide scholarships and research facilities, including the use of their own laboratories, to help achieve international cooperation with and among developing nations. They should also take into account the often-critical need for travel money.
- The training of new scientists and engineers should be aided by networks that have already been established by practicing professionals in diverse specialties. These networks should be given enduring support by academic, governmental, intergovernmental, and private organizations.

5. Support the development of digital S&T information sources

- Foundations should provide funding and expert support for libraries to maintain electronic gateways for the sharing of digital information among researchers, teachers, and learners.
- Foundations should provide funds for establishing major hubs in the developing world for sharing digital information with research institutions in the industrialized world. This will facilitate access to some materials (in video format, for example) that require wide bandwidth not necessarily available everywhere. It will also serve the eminently sensible goal of backing up original material.

6. Play an important role in implementing the actions proposed in this report, either individually or in partnerships with national governments; private sector; and international, regional, and local agencies

- Foundations should promote imaginative partnerships between the public and private sectors that bring the benefits of scientific discoveries and technological innovations to all of the world’s people. Such partnerships can invigorate education, conduct research of mutual interest, and capitalize on the results of the research for the benefit of society.
- Foundations should provide assistance to help stimulate long-term public and private sector investments in effective local ‘knowledge – based infrastructure’ – the entire system of national private entrepreneurship, human resources, investment, and exploration of the advancing frontiers of S&T knowledge.

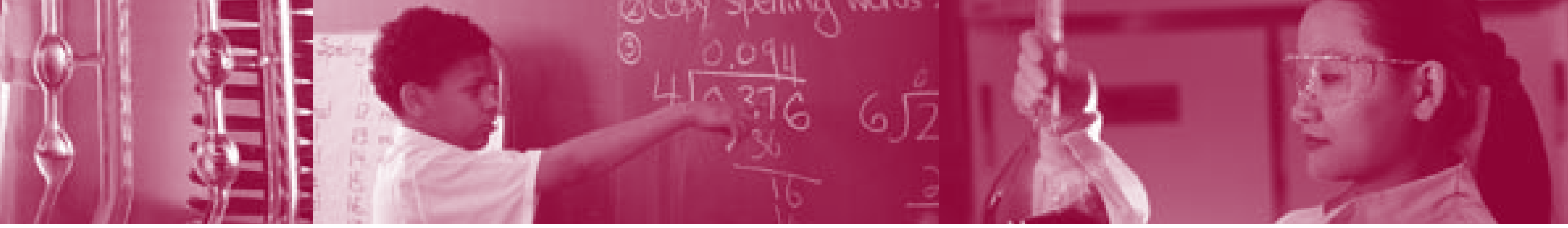
Agenda for local, national, and international private sectors (for-profit entities)

1. Participate in national efforts to identify S&T goals and priorities

- The private sector in developing nations should be an active participant in governmental efforts to plan the development of national capabilities in science and technology.

2. Support research and development efforts in developing nations that address local and global needs

- The international private sector should participate in incentive programs for creating in-house corporate research units and hiring scientific talent. Such incentives should essentially be spurs that encourage, not replace, the private sector's own profit-motivated desire to take these steps. For example, tax rebates and national recognition for industries involved in building their human-resources capacity – say, through internship programs and contractual research – could pay sizeable dividends to the private and public sectors alike.
- The international private sector should help finance and participate in centers of excellence – research programs, within a university, a research institute, or operating independently, typically located in one geographical location, and deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output – whether of local, national, regional, or international status.
- The international private sector should financially support the creation of new virtual networks of excellence (VNE) – research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the internet and the World Wide Web, deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output – nationally, regionally, and globally.
- The multinational private sector should actively encourage extensions of the grace period under the Trade – Related Aspects of Intellectual Property Rights (TRIPS) to 2016 for most developing nations.
- S&T capacity building in the developing nations would be helped by corporate segmentation of the global marketplace, distinguishing between technologically advanced and poorer, technologically deprived nations. These image – improving but also commercially rewarding actions could increase the countries' ability to develop their own S&T programs, keep the local prices of products from rising beyond the reach of most of the population, and permit the development of locally produced versions.



Using the pharmaceutical industry as an example, the following recommendations apply to the multinational private sector based in S&T-advanced countries:

– Patent fees should be waived on the few existing patented tropical-disease drugs, and in some cases make them available for free.
– Automatic licensing should be allowed for S&T-proficient as well as S&T-developing nations to produce generic drugs (as long as they honor a ban on exportation of the generics to the markets of the high-income countries).
– Real partnerships should be created with developing nations' private sectors.
– Extensions of the grace period under TRIPS to 2016 should be encouraged for most developing nations.
– Special partnerships should be created for the advanced developing nations that include customized licensing, and experimentation with a few drugs at differential pricing.
– Appropriate incentive policies in industrialized nations should be supported to promote technology transfer – for instance, tax breaks for companies that license technology to developing nations.

- The private sector should support the option of national sectoral funding for research and development that significantly enhances science and technology capacity.

3. Participate in government-university-industry partnerships for strengthening S&T capacity

- Corporations should join with governments, universities, and research institutes to experiment with partnerships and consortia for addressing research areas of potential local benefit.

4. Help developing nations to upgrade their educational institutions and programs

- The private sector should support and sponsor programs for providing high-quality training for S&T teachers.
- The private sector should support government awards of special fellowships or grants, designed to provide adequate research support and income supplements, to outstanding young scientists who work in developing nations for a period of time. Such special treatment may require local institutional flexibility, but it would be amply justified by the fundamental benefit of stimulating and retaining the local talent. For their part, governments of developing nations should provide re-entry grants to encourage young scientists trained in the industrialized world to return home.

5. Help provide information on S&T resources and issues to the public

- The private sector should support and provide necessary information to the government advisory and assessment programs on health and safety issues regarding products and services. Each nation involved in the development, production, or use of new technologies, such as those deriving from biotechnology, should have the means for assessing and managing their benefits and risks. Governments should therefore ensure that expert scientific advice is available from regional or international sources not only to assure effective adoption of new technologies but to facilitate implementation of public health, human safety, and environmental guidelines or regulations associated with their potential side-effects.

Agenda for nongovernmental organizations

1. Encourage innovation in disseminating the results of research and in turning them into new products and services that address local needs

- Nongovernmental organizations should support and undertake innovative programs to provide information to the public, including:
  - Cooperative partnerships among local citizens and research institutions in sharing up-to-date information of local relevance;
  - Empowerment of social entrepreneurs for supplying products and services significantly below market prices to people in need;
  - 'Information kiosks,' either publicly funded or for-profit, to provide useful information obtained from the Internet.

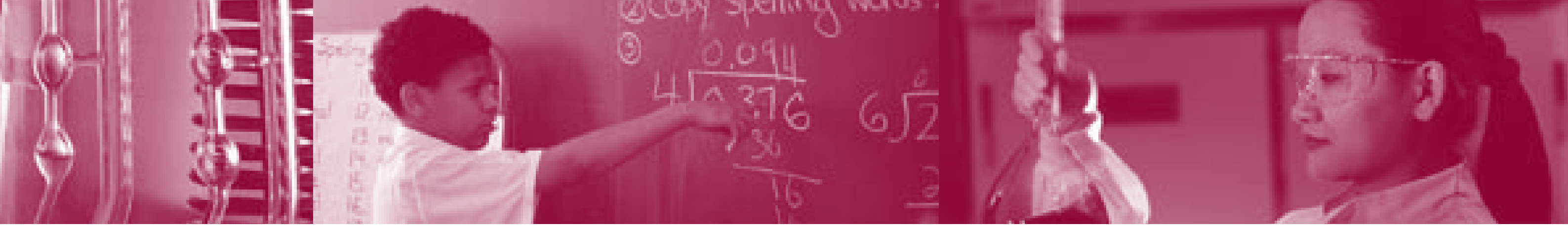
2. Provide information to the public about S&T issues relevant to developing nations

- Nongovernmental organizations should provide information to the media and decisionmakers that identifies and protects the public-goods domain and allows for the public funding of public-goods research. The nongovernmental organizations should therefore help:
  - Ensure that public priorities are addressed by public-private partnerships,
  - Ensure that the benefits of publicly funded research are available to all,
  - Promote open access to scientific databases.

Agenda for the media

1. Assume major responsibility for educating the nation's public on S&T-related issues

- High-quality coverage of these issues requires the S&T community to pay more attention to the media and participate more fully in public discussions and debates. In such interactions, practitioners should endeavor to explain technical issues in non-technical language.



- Regarding scientific or technical matters on which public-policy choices are to be made, the media should seek out the best S&T sources for their articles and programs. In a similar spirit, reporters and editors should not artificially generate controversy by seeking out minority positions that appear to highlight the adversarial aspects of S&T-related questions, particularly when the professional community has actually achieved broad consensus.

2. Use the new electronic media to provide the public with information related to issues of science and technology

- A wide array of communications technologies – print, television, radio, cellular telephone, World Wide Web, the Internet, among others – should be utilized in disseminating to the public the results and public policy implications of publicly or privately funded research that addresses national or local needs.

Annex C: Study panel biographies

Co-chairs

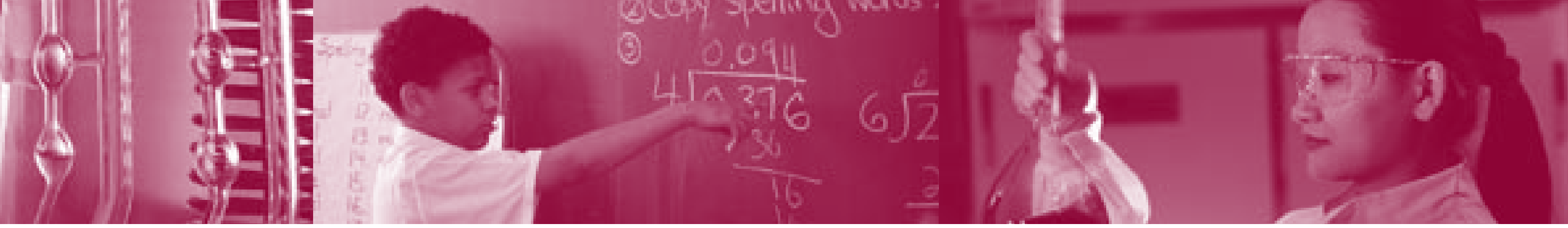
Jacob PALIS is a Professor at the Instituto Nacional de Matemática Pura e Aplicada (IMPA) in Rio de Janeiro, Brazil, and its former Director (1993-2003). He is a graduate of the Federal University of Rio de Janeiro and received his Ph.D. from the University of California, Berkeley. His primary research is in the area of dynamical systems, to which he made fundamental contributions – culminating with the proposal of a comprehensive program to understand most chaotic systems and thus generating a great deal of scientific activity. His intellectual leadership was also behind the formation of an accomplished school of dynamicists in Latin America. Dr. Palis was President of the International Mathematical Union and Vice-President of ICSU. He is now a member of the Science Institute Group – Princeton, chair of the ICTP Scientific Council, member of the Scientific Advisory Board – Collège de France and ETH – Zurich Math Institute, and serves as a consultant to several international research and educational agencies, including UNESCO, the U.S. NSF, CONICYT in Chile, CONACYT in Mexico, and CSIC in Uruguay; and has coordinated joint research projects in mathematics between Brazil and the United States, France, the Soviet Union, England, Chile, Mexico, and other countries. Dr. Palis is Secretary General of the Third World Academy of Sciences, a member of the Brazilian Academy of Sciences, and a foreign member of the Indian, Chilean, French, Mexican, and United States Academies of Sciences. He has been awarded several national and international prizes.

Ismail SERAGELDIN is the Director of the newly established Bibliotheca Alexandrina in Egypt, and he chairs the Boards of Directors for each of the seven research institutes and three museums affiliated with the Bibliotheca Alexandrina. Previously he served as Vice President of the World Bank (1992-2000); Chairman of the Consultative Group on International Agricultural Research (CGIAR, 1994-2000); Chairman of the Consultative Group to Assist the Poorest (CGAP), a micro-finance program (1995-2000); Chairman of the Global Water Partnership (GWP, 1996-2000); and Chairman of the World Commission for Water in the 21st Century (1998-2000). Dr. Serageldin worked in a number of capacities at the World Bank (1972-2000) and has published and lectured widely. He holds a Bachelor of Science in engineering from Cairo University and master's and Ph.D. degrees from Harvard University, and he has received 15 honorary doctorates. Dr. Serageldin currently serves as Distinguished Professor at Wageningen University in the Netherlands and as Chair and member of a number of advisory committees for academic, research, scientific, and international institutions' and civil-society efforts. He is a Fellow of the Third World Academy of Sciences.

Panelists

Jorge ALLENDE is a Professor in the Institute for Biomedical Research, Faculty of Medicine, University of Chile. Dr. Allende made pivotal contributions to the understanding of protein synthesis through his characterization of elongation factors and mammalian aminoacyl-transfer RNA synthetases. He was also a pioneer in studying the mechanism of hormonal induction of amphibian oocyte maturation. In more recent years, Dr. Allende has been studying the structure, function and regulation of two ubiquitous protein kinases, CK1 and CK2, that are involved in the phosphorylation of key cellular proteins. In addition to his prominence in scientific research, Dr. Allende has been a leader, both nationally and internationally, in the field of science education and in the establishment of scientific networks in Latin America. He is the current President of the International Cell Research Organization and President of the Council of Advisors on Health Research of the Pan-American Health Organization. He is a member and former President of the Chilean Academy of Sciences, a member of the Latin American Academy of Sciences, a Fellow of the Third World Academy of Sciences, and a Foreign Associate of the U.S. National Academy of Sciences and of the U.S. Institute of Medicine.

Catherine BRÉCHIGNAC is a Professor of Physics at the Laboratoire Aimé Cotton in Orsay, France. From 1997-2001, she was Directeur Général of France's Centre National de la Recherche Scientifique (CNRS). She is a specialist in the interdisciplinary study of the nano-physics of 'aggregates,' small clusters of a few thousand to a few million atoms. A graduate of Ecole Normale Supérieure, Dr. Bréchignac began her career in atomic physics and made significant contributions to the understanding of radiative collisions between atoms in laser light. She has been scientific director of the Physical Sciences and Mathematics Department of CNRS, and



director of the Aimé Cotton Laboratory in Orsay. Dr. Bréchignac is a Chevalier of the Legion of Honor and received the Academy of Sciences award in 1991 and the CNRS Silver Medal in 1994. She is a member of the French Academy of Sciences.

Ledivina V. CARIÑO is a University Professor at the University of the Philippines, that institution's highest academic rank, and is a former dean of the UP National College of Public Administration and Governance. She received a Ph.D. in sociology from Indiana University (USA) in 1970, after having obtained a Bachelor of Arts in public administration from the University of the Philippines and a Master of Arts in political science from the University of Hawaii. Dr. Cariño was elected to the Philippine National Academy of Science and Technology in 1995 and has served as Secretary of its Executive Council since 2002. Her research has focused on the evolution, structure, and process of public administration in developing nations, with special attention to issues of local governance, corruption and ethics, democratic public administration, and voluntary sector management.

Muhammad I. CHOUDHARY is Professor of Chemistry and Acting Director of the Hussein Ebrahim Jamal (HEJ) Research Institute of Chemistry, the largest academic research institute of the University of Karachi, Pakistan. He also heads that institution's single-crystal X-ray diffraction and molecular modeling laboratories. His work in X-ray crystallography has resulted in determination of the 3-D structure of several dozen novel products, both natural to the marine environment and synthetic. The plant-screening laboratory of H.E.J. Research Institute of Chemistry, working under Dr. Choudhary's guidance, is carrying out a screening program for the active components of plants and animals commonly found in Pakistan. He has over 300 research publications in leading international journals and is the co-author of two books. Dr. Choudhary was the Secretary-General of the Chemical Society of Pakistan (1995-1998), Editor of the COMSTECH Newsletter, member of the Executive Council of ANRAP, and Fellow of LEAD International. He is a Fellow of the Third World Academy of Sciences and the Islamic Academy of Sciences.

Thomas EGWANG is Senior Research Scientist in the Department of Medical Parasitology at the Medical Biotechnology Laborities in Kampala, Uganda. Recently named a Howard Hughes Medical Institute Scholar, he received his Ph.D. in immunology from McMaster University in Canada in 1984 and did postdoctoral research in the United States at Case Western Reserve University School of Medicine and the University of California, Berkeley, and in Gabon at the Centre Internationale de Recherches Médicales de Franceville. His recent research has been in the area of biochemical drug targets and antiparasitic-drug resistance. In 1995, Dr. Egwang received the Career Development Award from the World Health Organization. He is a Fellow of the Third World Academy of Sciences.

Julia MARTON-LEFÈVRE is Executive Director of Leadership for Environment and Development (LEAD) International. Prior to her joining LEAD, she was the Executive Director of the International Council for Science (ICSU) in Paris. She serves on the boards of numerous international organizations, including: the World Resources Institute (as Vice Chair), the International Institute for Environment and Development, and the environmental advisory boards to the Dow Chemical Company and The Coca Cola Company. She is also a Trustee of the St. Andrews Prize and the 1999 recipient of the AAAS Award for International Cooperation in Science. She has degrees in history, ecology, and environmental policy. Born in Hungary, she holds both French and U.S citizenships.

Mamphela RAMPHELE is Managing Director for Human Development at the World Bank. In this capacity she oversees the Bank's activities in health, education, social protection and the use of information and communication technologies to enhance capacity for knowledge-based development. She joined the World Bank in May 2000. Dr. Ramphele started her career in South Africa in the 1970s as a student activist in the Black Consciousness Movement. She has worked as a medical doctor, civil -rights leader, community-development worker, academic researcher, and university administrator. Joining the University of Cape Town as a research fellow in 1986, she was appointed Deputy Vice-Chancellor five years later. In September 1996, Dr. Ramphele took up the post of Vice Chancellor, becoming the first black woman to serve in this position at a South African university. She holds an M.D. from the University of Natal, a Ph.D. in social anthropology from the University of Cape Town, a B.Com. in administration from the University of South Africa, and diplomas in tropical health and hygiene and public health from the University of Witwatersrand. She was elected to the South African National Academy of Sciences in 1995.

Neil L. RUDENSTINE is Chair of the Advisory Board of ARTstor at the A.W. Mellon Foundation in New York. He was President of Harvard University from 1991 to 2001 and served as Executive Vice President of the Andrew W. Mellon Foundation from 1988 to 1991. During the two preceding decades, he was a faculty member and senior administrator at Princeton University. A scholar of Renaissance literature, Dr. Rudenstine was a professor of English who went on

to hold the posts of Dean of Students (1968-1972), Dean of the College (1972-1977), and Provost (1977-1988). Previously, he served at Harvard from 1964 to 1968 as an Instructor and then an assistant Professor in the Department of English and American Literature and Language. He received his bachelor's degree from Princeton in 1956 and studied for the next three years as a Rhodes Scholar at New College, Oxford University, where he earned a second B.A. and an M.A. In 1964, he was awarded a Ph.D. in English from Harvard.

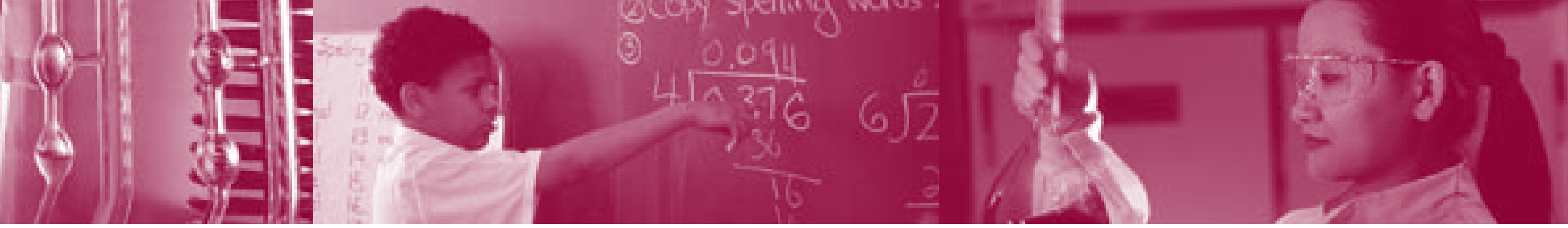
P.N. TANDON is Emeritus Professor at the All-India Institute of Medical Sciences, New Delhi, and Megh Nad Shah Distinguished Fellow of the Indian National Science Academy. A neurosurgeon by profession, he is a Fellow of the National Academy of Medical Sciences and past President of the Indian National Science Academy and the Neurology Society of India. Dr. Tandon is also a Fellow of the Norwegian Academy of Sciences and the Third World Academy of Sciences; the President of the National Brain Research Centre; former Co-Chairman of the InterAcademy Panel on International Issues; and an elected member of IBRO, the Society of Neurological Surgeons (USA), the Society of Neurosciences (USA), and the Royal Society of Medicine (UK). He has edited 14 monographs and two books and has published over 200 scientific papers. Dr. Tandon has been a member of the Science Advisory Council to the Indian Prime Minister and is a recipient of numerous honors and awards, including the national award – Padma Bhusan – from the President of India.

ZHAO Shidong is a Research Professor of Forest Ecology at the Institute of Geographic Science and Natural Resource Research (IGSNRR), Chinese Academy of Sciences, and Vice-Chair of the Scientific Committee of the Chinese Ecosystem Research Network. He graduated from the Department of Forestry of N.W. Agricultural University in 1963 and received his Ph.D. from the Institute of Applied Ecology of Chinese Academy of Sciences in 1967. Since then, Dr. Zhao has been doing research on the taxonomy and distribution of plants, the effects of human activities on ecosystem biodiversity, the impacts of climate change on ecosystems, land-use change, and the structure, function, dynamics, and management of ecosystems. He has published over 100 papers and 14 books on these subjects. As a visiting scientist, Dr. Zhao did research in the School of Natural Resources, University of Michigan, from 1983 to 1985. He has also been working on several international programs as a member of the Steering Committee of International Long-term Ecological Research (ILTER), the Assessment Panel of the Millennium Ecosystem Assessment (MA), and the Regional Vice-Chair of Commission of Ecosystem Management, IUCN.

Study panel staff

John P. CAMPBELL (Study Director) is Associate Director of the InterAcademy Council. He has been Director of the May 2000 World Conference of Academies on a Transition to Sustainability in the 21st Century, in Tokyo; Staff Officer of a joint U.S. National Academy of Sciences-Mexican Academy of Sciences review of graduate programs of the National Autonomous University of Mexico (UNAM), in Mexico City; Director of the June 1996 World Forum of Academies of Science and Engineering on the Future of Cities, in Istanbul; Staff Officer of the October 1993 'World Population: Summit of the World's Scientific Academies' in New Delhi; and Project Director of the Government-University-Industry Research Roundtable's Working Group on the Academic Research Enterprise, U.S. National Academies, in Washington, D.C.

Steven J. MARCUS (Report Editor) is an editorial consultant. He has been Editor-in- Chief of Technology Review, a magazine published by the Massachusetts Institute of Technology; Editor-in-Chief of Issues in Science and Technology, a journal of the U.S. National Academies; and Executive Editor of High Technology magazine. He has also worked in daily journalism as a business reporter for the New York Times and as Science/Medicine Editor of the Minneapolis Star Tribune.



Annex D: Glossary

Advanced research institute: a research institution managed by a university or operating independently, typically in one geographical location in either an industrialized or more advanced developing nation; and organized to conduct a diversity of research programs deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output.

Center of excellence: a research program managed by a university, an advanced research institute, or operating independently, typically in one geographical location, and deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output.

Digital libraries: collections of information – originally in the form of printed books, journals, and monographs; databases; photographs, motion pictures, and videos; sound recordings; and digital format – made accessible to everyone, everywhere in electronic format through organized sites on the World Wide Web.

Intellectual property rights: rights awarded by society to individuals or organizations over inventions, literary and artistic works; and symbols, names, images, and designs used in commerce, giving the titleholders the right to prevent others from making unauthorized use of their property for a limited period.

Millennium Development Goals: a global agenda agreed upon by leaders of national governments assembled at the United Nations Millennium Summit of September 2000, identifying specific goals for addressing the following issues: extreme hunger and poverty, universal primary education, gender equality, child mortality, maternal health, infectious diseases, environmental sustainability, and global partnerships for development.

Millennium Science Initiative: an international program (with major funding from the World Bank) for building S&T capacity through (1) competitively selected MSI Institutes and smaller 'nuclei,' centers of excellence located within existing institutions; (2) a Global Science Corps that sends scientists from S&T-advanced and S&T-proficient countries to train and collaborate with their counterparts in S&T-developing and S&T-lagging countries; and (3) infrastructure enhancement, especially for instrumentation and information/communications technology.

Merit review: an evaluation of a research program, performed by experts unaffiliated with the program under review, assessing the program's technical merit and potential benefits to society, incorporating such techniques as peer review teams, relevance -review panels, or benchmarking studies.

National academies of sciences, engineering, and medicine: merit-based autonomous institutions, in which peers elect new members in recognition of their distinguished and continuing professional achievements, elect their own officials, perform programs of independent work, and inform the general public and national decisionmakers on science and technology aspects of public policies.

Research and development: basic (or fundamental) research, driven primarily by a desire to know; strategic research, driven by a desire to know and its potential use; applied research, driven primarily by its potential use; adaptive research, undertaken to adapt a given product or technology to local conditions; and development, undertaken to create new products and services.

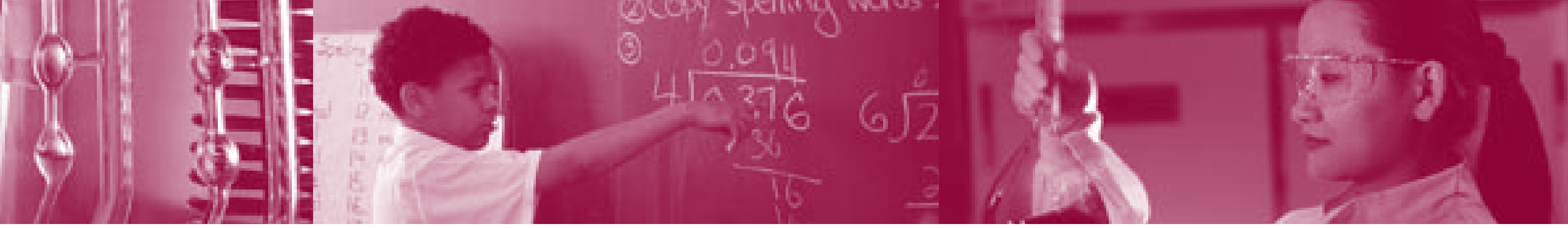
S&T-advanced country: a country with scientific and technological strength in most research areas and a substantial S&T enterprise in personnel, infrastructure, investment, institutions, and regulatory framework.

S&T-proficient country: a country with scientific and technological strength in several research areas and a growing S&T capacity in all aspects, including personnel, infrastructure, investment, institutions, and regulatory framework.

S&T-developing country: a country with scientific and technological strength in one or more research areas, but generally lacking important aspects of S&T capacity in personnel, infrastructure, investment, institutions, and regulatory framework

S&T-lagging country: a country with little scientific or technological research strengths and no discernable overall S&T capacity in personnel, infrastructure, investment, institutions, and regulatory framework.

Science and technology: the full range of scientific, engineering, and health fields and disciplines, including aeronautics and astronautics; agricultural sciences; anthropology; biology; brain and cognitive sciences; chemical engineering; chemistry; civil and environmental engineering; earth, atmospheric, and planetary sciences; economics; electrical engineering and computer science; systems engineering; health sciences and technology; materials science and engineering; mathematics; mechanical engineering; nuclear engineering; physics; political science; psychology; and sociology.



Science and technology capacity: the available personnel, infrastructure, investment, institutions, and regulatory framework in a country to generate activities and acquire scientific knowledge and technological capabilities for addressing with competence and creativity local, national, and international needs.

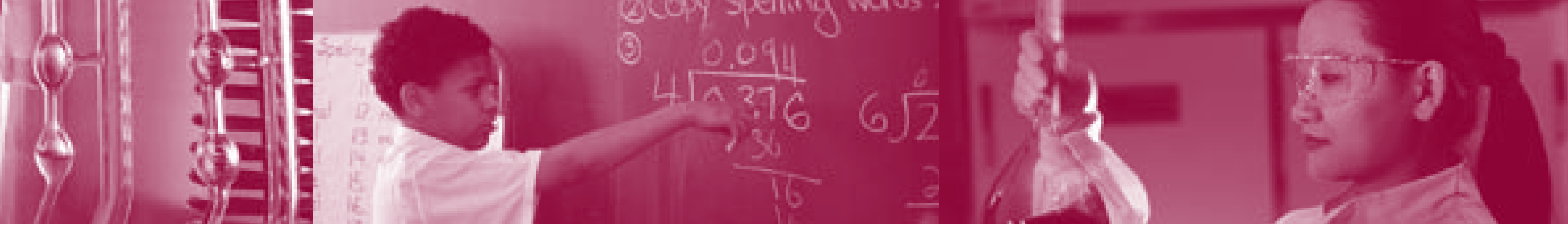
Sectoral funds: a portion of a nation's tax levies on for-profit corporations redirected into a special fund for financing the conduct of research in selected science and technology areas of economic interest to the nation.

Virtual institute: a set of research programs undertaken by research personnel located in different geographical locations, communicating and collaborating primarily via new technologies such as the Internet and the World Wide Web.

Virtual network of excellence: a set of research programs jointly sponsored and conducted by research institutes in different geographical locations, with research personnel communicating and collaborating primarily via new technologies such as the Internet and the World Wide Web, deemed by merit review to be of the highest international quality in personnel, infrastructure, and research output.

Annex E: Acronyms and abbreviations

AERC	African Economic Research Consortium
CAETS	Council of Academies of Engineering and Technological Sciences
CGIAR	Consultative Group on International Agricultural Research
FAO	United Nations Food and Agriculture Organization
GDP	Gross domestic product
IAC	InterAcademy Council
IAMP	InterAcademy Medical Panel
IAP	InterAcademy Panel on International Issues
ICSU	International Council for Science
ICTP	Abdus Salam International Centre for Theoretical Physics
IFS	International Foundation for Science
INASP	International Network for the Availability of Scientific Publications
LEAD	Leadership for Environment and Development International
MSI	Millennium Science Initiative
NSF	U.S. National Science Foundation
NSRC	U.S. National Sciences Resources Center
OECD	Organisation for Economic Co-operation and Development
PPKIP	Pilot Project of the Knowledge Innovation Program, Chinese Academy of Sciences
R&D	Research and development
S&T	Science and technology
TOKTEN	Transfer of Knowledge and Technology Expatriate Nationals Program
TRIPS	Agreement on Trade-Related Aspects of Intellectual Property Rights
TWAS	Third World Academy of Sciences
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USHEPiA	Research Initiative of the University Science, Humanities, and Engineering Partnerships in Africa
VNE	Virtual network of excellence
WHO	World Health Organization



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