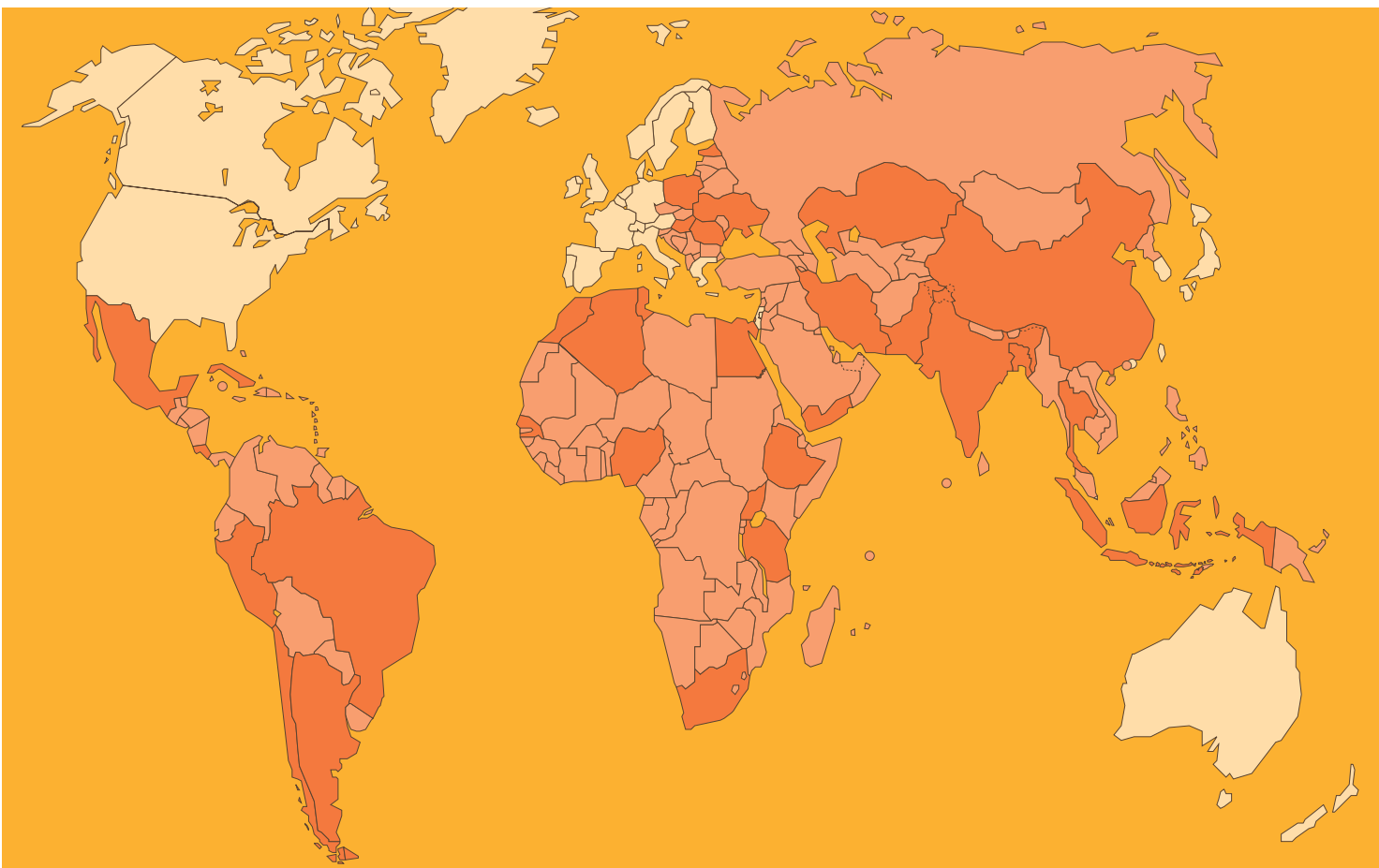
Promoting Life Science Research and Training in Developing Countries

A Need for Concerted Action



HFSP twas wellcome trust EMBO

Report of a meeting held in Trieste, Italy, 8-10 November 2003

Summary

In November 2003, the Human Frontier Science Program (HFSP), the Third World Academy of Sciences (TWAS), The Wellcome Trust and the European Molecular Biology Organization (EMBO), co-sponsored a workshop in Trieste, Italy, devoted to the challenge of how funding agencies could promote life science education and research in developing nations. The Trieste meeting brought together leaders of science funding agencies and research centers from Africa, Latin America, Asia, the Middle East, the Newly Independent States, Europe and the United States, with extensive and highly diverse experience in supporting research and science education in a wide range of developing regions. All participants agreed that socio-economic development in the 21st century crucially depended on the promotion of life science education and research. Participants also agreed that in the developing world this key component was often critically lacking, with serious consequences for economic growth, healthcare and educational systems in these regions.

Participants described initiatives, some already in place, to promote the life sciences in the developing world. These include home-grown centers of excellence in nations such as China, India and South Africa, which are having significant impact on levels of science training and research locally, and in disseminating scientific culture to surrounding regions; multilateral training centers such as the International Centre for Genetic Engineering and Biotechnology (ICGEB) in Trieste and New Delhi; regional networks such as the Latin American Network of Biological Sciences (RELAB) or the International Brain Research Organization (IBRO); partnerships, twinning arrangements and sandwich programs for the mutual enrichment of individual scientists and laboratories in developed and developing nations; and science academies and other regional associations that support science education, research and capacity building, and can help integrate local scientific communities into public policy making and private initiatives.

A number of issues emerged from the meeting that must be tackled if the developing world is to benefit from advances in life science research. Participants at the meeting therefore strongly recommend that action be taken on the following:

- A clear commitment must be made to quality science and to scientific approaches to problem-solving in the developing world
- There is a need to promote research and training partnerships by creating long-term relationships between scientists in developing countries and their counterparts in the developed world and by setting up "sandwich programs" to enable students to work in developed countries as part of their training before returning home for their doctoral degrees
- "Brain circulation" rather than "brain drain" should be encouraged by facilitating short-term visits of scientists to laboratories in developed and developing countries
- Strong regional networks should be built of scientists within the developing world
- There is a need for Centers of Excellence that can also serve as regional centers of training and as loci around which research collaboration and informal networks can be organized
- Scientists from developing countries who are working in the developed world should be encouraged to participate in building scientific capacity in their home countries
- A greater degree of coordination of the activities of donor agencies is essential and initiatives must be adapted to local needs
- Information about programs for scientists in developing countries must be collected and made readily available
- Access to scientific information and publications must be improved
- The recent revolutionary advances in information technology and communications should be leveraged to speed the developing world's integration into global science.

Indeed, the crucial need for a central information source describing donor agency life science programs in the developing world became apparent at many points during the meeting's discussions. Donors can strongly enhance

the efficacy and cost-effectiveness of assistance when donor organisations with different expertise and priorities join forces to coordinate their support programs. As a first step to achieving these goals, participants at the Trieste meeting strongly recommend the establishment of a web-based network, the **Life Science Web for Developing Countries (or LSWDC)**.

The aim of the LSWDC would be to serve as a central web-based "bulletin board" listing donor programs in the life sciences for the developing world, making contacts between donor agencies and developing world scientists and students easier and more efficient, as well as promoting a greater degree of coordination among donor agencies themselves. With additional resources, LSWDC could also give both local and international visibility to life scientists in developing regions and help match them with possible sources of support. It could serve as an initial meeting site around which scientific interactions and networks in developing regions could evolve, and as a central information source vividly illustrating the value of life science research in developing societies. LSWDC could also help local and regional scientists in their efforts to make science education and capacity-building a central priority of national and local government and industry.

The proposal to create LSWDC also underlines a major theme of the Trieste meeting: the need to create a new transnational scientific culture, a "Global Science Corps", which encourages interaction and contacts between scientists from the developed and developing worlds. Participants described flexible "menus" of options encouraging the mobility of scientists to developing nations, and an increased desire among young scientists, perhaps partly in response to the violence and political turmoil of recent years, to bring their talents, skills, energies and experiences to developing nations.

Participants at the Trieste meeting believe that LSWDC has the potential for becoming a multi-faceted international resource for promoting life science education and research, one that could serve as a model for other areas of science and technology.

Many of the issues discussed in Trieste were later echoed in a report by the Interacademy Council, *Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology,* published in February 2004. As such, the Trieste meeting was a landmark in international cooperation, signalling the importance of bringing scientists and policy makers together in the task of promoting life science research in the developing world and giving leaders in funding the opportunity to strengthen their commitment to this task. By outlining clear directions for future cooperation, it is hoped that this high level meeting will have a lasting effect on scientific research and training in the developing world.

Life Science Research and Training in Developing Countries; a Need for Concerted Action

We live on a planet increasingly interwoven by a global market economy, by jet travel, the Internet, satellite communication, and other astonishing technologies. Yet the global dissemination of science –that most fundamental and universal of human cultural achievements– has lagged far behind. Spurred in large part by the rise of biotechnology and genomics, government and business leaders in developed nations have come to view a nation's investments in the life sciences as central to economic growth, improved health care, intelligent ecosystem management, and an advanced educational system. The life sciences have joined information and computer sciences as driving engines of the knowledge-based culture of the 21st century. Yet this central component of modern knowledge-based societies remains poorly developed in many regions of the world.

In November 2003, the Human Frontier Science Program (HFSP), the Third World Academy of Sciences (TWAS), The Wellcome Trust, and the European Molecular Biology Organization (EMBO) co-sponsored a workshop in Trieste, Italy devoted to the challenge of how funding agencies could most effectively promote life science education and research in developing nations. Funding agencies, the primary supporters of scientific research and training in most high-income countries, are in a unique position to promote a more productive, better-coordinated approach to the problem of seeding and fostering life sciences in the developing world. The Trieste meeting brought together leaders of science funding agencies and research centers from Africa, Latin America, Asia, the Middle East, the Newly Independent States, Europe and the United States, with extensive experience in supporting research and science education in a wide range of developing regions.

All participants in Trieste strongly believed that life sciences should be a central component of any thriving society's educational system; of its health care system, agricultural and technological development, and environmental planning. However, even for many relatively high-income nations of the developed world, building and sustaining thriving life science programs has proved to be difficult. The challenges are especially daunting for resource-constrained countries of the developing world, which often lack much of the basic educational and economic infrastructure, as well as the research traditions, that feed the life science enterprise. Yet despite often formidable economic, educational and political hurdles, there are many creative initiatives now being pursued and planned in developing countries to seed and nurture life science education and research.

A representative sample of these innovative actions was presented and discussed at the Trieste meeting, along with a most useful and well-received statistical overview of scientific research and education in resource-constrained countries prepared especially for the meeting by Alexandra Moreno Borchart (EMBO)[1]. From these presentations and discussions, key guiding principles for optimizing the effectiveness of funding programs emerged. Moreover, many discussants remarked that perhaps the most stimulating aspect of the meeting was the opportunity to hear about the funding programs in which their colleagues were engaged.

Yet at the same time, the Trieste meeting's lively exchanges pointed to a fundamental gap in existing support strategies: the lack of a central information source describing donor agency life science programs in the developing world.

1: [http://www.embo.org/publications/world/report_03.pdf]

Thus as a manageable first step to confronting an enormous challenge, participants in the Trieste meeting strongly **recommend the creation of a central, web-based information source as a new platform to more effectively match funding programs and resources to potential opportunities and scientific recipients in developing nations: a Life Science Web for Developing Countries (LSWDC).** This proposed web-based network will be described in more detail in the body of this report, along with a distillation of our discussions.

There is growing recognition that capacity-building in science and technology in general, and in the life sciences in particular, is not a luxury for a developing nation seeking to better the welfare of its citizens in a real and sustainable fashion, but a necessary condition. Gerald Keusch (Fogarty International Center, USA) spoke of an emerging paradigm shift in how the relationship between the life sciences and health care in the developing world is viewed, the result in part of the World Bank's 1993 *World Development Report*, which is based on the conclusion that improving the overall health of a country's population is directly dependent on the application of new knowledge growing out of scientific and medical research. Scientists in a developing nation, said Frank Gannon (EMBO), can be seen as the critical "antennae" tuned to receive new waves of scientific advances from the rest of the world, and thus serve also as critical motors for economic, educational and cultural growth in developing societies. They can also help to identify excellent targets for both local and international investment. As Jorge E. Allende Rivera (Institute of Biomedical Sciences, Chile) stated: "Show me a country that has come out of underdevelopment that has not put a big emphasis on investing in science and technology: you can't find any".

Critical developments in web-based communication technologies and within the life sciences themselves make this a particularly propitious time for seeding such investments. Hans Hagen (The Wellcome Trust, UK) spoke, for example, of an ongoing collaborative effort to organize a series of bioinformatics workshops in Africa focused on the analysis of genomes of pathogenic organisms. "There's a window of opportunity right now to train people to use the information on pathogen genomes available on the web", said Hagen, an opportunity that could be used as an accelerating force to "really leap-frog in terms of the ability [of African scientists] to access and apply the information that is out there", and to develop scientific capacities currently lacking. The African Genome Initiative has recently launched a peer-reviewed journal, "Genomics and African Society" (www.africagenome.co.za) reflecting these new opportunities.

Indeed, the sequencing of the genomes of humans and an ever-growing list of organisms –from bacterial pathogens to agricultural crops, from laboratory model organisms to livestock– has made it profoundly clear that underlying the astonishing diversity and complexity of living processes on earth is the universal genetic language of DNA, and thus that these processes can be analysed by common methods. At the Trieste meeting, participants heard how the same molecular genetic toolkit is being used by local scientists studying the deadly malaria parasite in Uganda, valuable copper-leaching bacteria in Chile, and silkworms in China. Such diverse applications of genomic science are symbolic of the universal value of life science research and education: of how the same global body of knowledge can be adapted to local medical, agricultural, economic and ecological challenges.

1 • Act Locally, Think –and Interact– Globally: Adapting Support Strategies to Local Landscapes

In 2001, HFSP and the European Science Foundation sponsored a meeting of funding agencies in Strasbourg that led to a report, *Toward a New Paradigm for Education, Training and Career Paths in the Natural Sciences*[2], also known informally as the "Tree-Report" because of its cover image and guiding metaphor. The report proposed replacing the traditional image of science education and training, which is often represented as flowing through a unidirectional and unfortunately impermeable pipeline. Instead, the report proposed a new, organic image of education and training better attuned to the needs of both science and society: a Tree of Science with a richly ramifying, highly permeable network of roots and branches reflecting the wide and reticulating range of inputs into the scientific enterprise and the range of career opportunities for students having a solid science background. Stated in these terms, the 2003 Trieste meeting was devoted to the daunting challenge of seeding and nurturing such self-sustaining Trees of Science in disparate, highly-variable regions of the developing world: of adapting support strategies to local landscapes.

Participants in the Trieste meeting agreed that there could be general guiding principles, but no "grand unified theory", for promoting life sciences in developing nations. "We need to recognize and avoid a 'one-size fits all'

2: [http://www.hfsp.org/pubs/Position_Papers/funders.htm]

approach", said Joe Harford (National Cancer Institute, USA) "and to tailor and customize the solutions we bring to countries to the issues that are characteristic of that country". There are, for example, countries in which an extensive "root system" for the Tree of Science already exists: China, India, countries in Eastern Europe and among the Newly Independent States have good basic education systems for at least a significant subset of their citizens and the appropriate governmental and societal structures are in place. Critically, these countries also have long-term scientific traditions, a culture of supporting academic excellence, and in some cases, existing or emerging centers of scientific excellence, that can be rather rapidly channelled toward life science education and research. In other regions, especially in the least developed countries, this educational root system and scientific cultural tradition is deficient or lacking, and there is a very small population of research scientists. Thus participants discussed programs to support primary science education in developing nations, programs that, in the words of Jill Conley (Howard Hughes Medical Institute [HHMI], USA) could "demonstrate the use of an effective, low-cost modular science education program that can be adapted and applied elsewhere".

"We need a palette of strategies", said Ida Nicolaisen (Nordic Institute of Asian Studies, Denmark), "that take into account the great variability of countries in terms of socio-economic profile, education systems, research traditions and other factors". Mohamed Hassan (TWAS) emphasized that in order to elevate the status of life sciences in Africa and other least developed countries, high-quality life science must be mobilized and applied to real-life problems, and to sustainable economic development. This perspective was strongly echoed by Zhu Chen (Chinese Academy of Sciences, China): "In developing countries, we need to be very sensitive to sustainability for science and development. While we have to support basic research, we also have to pay close attention to translational research. Not only in biomedicine, but in agriculture, ecosystems, food supply and water resources".

Moreover, as Dr. Chen, Torsten Wiesel (HFSP) and others remarked, the life sciences have become a nexus for all the natural sciences and many cutting-edge technologies. "Life science and biotechnology are becoming more and more multidisciplinary", said Dr. Chen. "There is not only cross-talk between different disciplines within life sciences and biotech areas, but also cross-talk between biology and mathematics, physics and chemistry, and with the social sciences as well". Thus support of life sciences can promote interactions and advances across a wide spectrum of disciplines and technologies and across the entire gamut of the natural sciences.

In many developing countries whose governments lack the financial resources or political resolve to invest significantly in non-military scientific research, donor agencies from the West play a leading role in setting priorities and agendas. Traditionally, these donor agencies have tended to work autonomously. Each has had its own favored projects, and relatively little thought has been given to how these programs might overlap or complement the support programs of other agencies. "But now we see a new development among donor agencies", said Ida Nicolaisen. "We see moves toward a greater degree of coordination." This newly emerging cooperative spirit among donor agencies, embodied by the Trieste meeting itself, has enormous potential for both sides of the donor-recipient equation. Not only can this enhanced cooperation lead to a more efficient and synergistic allocation of donor agency resources, but it also offers opportunities for a more united front for applicants for aid, said Dr. Nicolaisen, enabling scientists in developing countries and partner scientists in the West, "to target donor agencies much more strategically", to make donor agencies aware of a wide range of important projects in life science research and education.

2 • A Life Science Web for Developing Countries

Despite this new spirit of donor agency cooperation, however, a major problem threading through many discussions in Trieste was the lack of a central information mechanism for learning what other agencies are doing. "There is quite a lot of duplication, overlapping of work", said Peter O'Neill (Department for International Development, UK). "There is no point in us doing a program, and someone else doing a similar program, and we all get to know about it a few years down the road." Indeed, said Mary Phillips (The Wellcome Trust, UK), "I suspect there is a lot of overlap and opportunities for collaboration even without additional expenditures".

It is thus strongly recommended that a collaborative web-site be created, a kind of international bulletin board, devoted to describing funding programs and opportunities in the life sciences in developing nations. A prototype for

such an integrated web-site, The Anglo-French Tropical Medicine Information Service[3], has been established by The Wellcome Trust and participating agencies in the United Kingdom and France. To begin with, funding agencies represented at the Trieste meeting would be asked to post, and regularly update, descriptions of their own developing world programs. Other funding agencies, by invitation and request, could then join this virtual consortium once it is up and running.

"I think what is really important is to have full information, a joint bulletin board", said Mohamed Hassan, "where we can put up the opportunities and possibilities for scientists in developing countries so that they know how to apply to each of these programs. We have our web-site, you have your web-site; but currently this is not being done in a coherent way".

This new web-site –tentatively called "Life Science Web for Developing Countries"– could continue to evolve and add additional useful features, given interest and dedicated resources. Especially valuable would be the incorporation of information from the other side of the donor-recipient equation: a parallel component on the web-site in which developing world science education and research programs in search of support could, in essence, post "advertisements for themselves", providing descriptions of projects and scientific activities along with contact information. "We need to know much more about the research institutes in the developing world", said Kerri-Ann Jones (National Science Foundation, USA). "We need to know where the centers of excellence are, where the scientists are, that we can partner with."

Indeed, a recent editorial in *Nature* [12 February 2004; 427: 571] noted the increasing number of large life-science oriented charitable organizations –the Bill and Melinda Gates Foundation, the Wellcome Trust, HHMI, the NIH's Fogarty Center and others– that support education and research in the developing nations. Crucially, however, the editorial then added: "Yet good databases of the support available for capacity building and of promising talent do not exist. They would surely reveal opportunities for agencies and Northern labs to work better together to concentrate support on priority areas, and on the best science, to nurture enduring centers of excellence".

3 • From Brain Drain to Brain Circulation

The loss of a country's best scientific talent to a small group of countries with advanced science –to the United States in particular– has become a major problem even for many high-income European nations. This problem of "brain drain" is particularly challenging for developing countries. How can scientific mobility across national borders be made bi-directional, promoting "brain circulation" rather than brain drain?

"We are very sensitive to the outcome of mobility [of scientific talent]", said Zhu Chen. "We think that if the mobility is just unidirectional, it will create brain drain. But if we can create mobility in a double sense, then we may have a situation of brain fostering and brain gain by taking advantage of world resources for education."

Such two-way mobility can take many forms, some of which are discussed later in this report. For instance, in so-called "sandwich programs" for education, students enrolled in a developing nation doctoral program can spend a period in a developed world doctoral program and laboratory before returning to their home country to complete their degree. Such sandwich programs have been quite successful in Sri Lanka, said Ranjan Ramasamy (International Council for Science [ICSU], France), and could be extended to a period beyond PhD-level training. "One of the problems that makes people uncomfortable working in developing countries is lack of communication, lack of exposure. If you can encourage short-term mobility that might make a big impact in developing countries and contribute to the development of science there."

In addition, individuals who make up a country's scientific "diaspora" can play a major role in developing science in that country, either as consultants and reviewers, or as a "talent reservoir" that can be drawn upon with sound strategies for attracting and supporting scientific talent. Through such strategies, China has recently experienced "a wave of repatriation of top-level life scientists", said Zhu Chen. Moreover, Martin Reddington (HFSP) added: "There may be an advantage to having a certain diaspora embedded in other scientific cultures that have very strong evaluative systems [for supporting science]. You may be able to bring in their expertise as peer reviewers, as consultants, in helping to build up your national research councils".

The Chinese diaspora, which is large and relatively organized, may serve as a model for other developing countries. Indeed, one additional "bulletin board"

3: [http://www.wellcome.ac.uk/en/aftmis/English/eng_home.html]

application of a Life Science Web for Developing Countries could be to promote contacts among a country's diaspora –both with each other, and with scientists and science and funding agencies working in their home countries. "I know a lot of African scientists working outside Africa", said Julia Hasler (UNESCO, France), "and they have very strong cultural ties with Africa, and would like to participate in capacity building in Africa. But I don't think that many agencies and foundations currently have a mechanism for doing this".

The other side of the brain circulation equation –encouraging mobility of Western scientists to the developing world– presents its own set of challenges. "We really need to create a new culture", said Torsten Wiesel, a trans-national scientific culture in which widespread groups of scientists in the West can find personal and professional value in forging contacts with developing world scientists. "It's very important for Western scientists to be involved, and not just funding agencies –for scientists to feel that they have an opportunity and responsibility to interact with their colleagues in developing countries."

Indeed, in countries such as Denmark, such interactions have proved highly rewarding to Western scientists. "Our experience in Denmark is that once we get scientists out into a developing nation", said Ida Nicolaisen, "there is a lot that comes back, it is very enriching for research communities to be exposed" to developing world scientists and scientific problems. Moreover, if such interactions are supported over a relatively long period [the Danish grants extend for 12 years], and involve post-docs and students of many ages, they often continue to perpetuate themselves when financial support ends. "These interactions can go on for [academic] generations", said Nicolaisen, as students and post-docs on both sides of the partnership mature into independent scientists with their own students and post-docs.

Nevertheless, in many Western countries such as the United States, young scientists are quite reluctant to step out of conventional career paths to work in developing nations. To encourage such mobility, said Kerri-Ann Jones, "we've developed a menu of options [at the National Science Foundation] to get U.S. scientists out into the world. We have international post-doc fellowships, for instance where students can go anywhere in the world for a period that can be as short as 3 months and as long as 2 years... We need to develop now a generation of scientists who understand the opportunities in the developing world". Such menus of options encouraging mobility should extend from young students to senior scientists. Dr. Wiesel suggested, for instance, that donor agencies seriously consider providing additional half-salary support for Western faculty (who normally receive half-salaries from their host institutions) who wish to spend their sabbatical years in a developing nation.

There are encouraging signs that the seeds for the new trans-national scientific culture evoked by Dr. Wiesel lie latent among many students and scientists in Western societies today, whose numbers may be increasing in response to the violence and political and cultural turmoil of recent years. In New York alone, said Ellis Rubinstein (New York Academy of Sciences, USA) "I see much more interest than one might expect in young people wanting to volunteer to go to developing countries and do exchanges, if somebody would help them learn how to do this... We desperately need this and the New York Academy is interested in fostering this, [in helping to create] what Harold Varmus calls a Global Science Corps." Mr. Rubinstein concluded: "If we wanted to bridge some of the gap, what would be better than to get some of our younger scientists who are brilliant and cutting-edge to go out into the developing world and learn [about the problems in these countries] and also help people who are there?"

4 • Partnerships and Support at all Levels of Life Science Education, Research, Publication and Development

At the Trieste meeting it was apparent that different funding agencies currently support work at many different levels of the "Tree of Science" in the developing world: through early education, post-doctoral fellowships, research grants and centers of excellence, among others. The Life Science Web for Developing Countries could provide better coordination among such diverse programs, and facilitate, for instance, interfaces between a funding agency supporting educational programs and a funding agency supporting research projects within the same developing nation.

Participants also stressed the critical importance of encouraging two-way mobility in North-South scientific partnerships, such as through the Ph.D. sandwich programs mentioned above. The participants of the meeting concluded, as did the Interacademy Council in a report[4], which appeared subsequent to the Trieste meeting, that

4: *Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology* [http://www.interacademycouncil.net/report.asp?id=6793]

"Sandwich programs... 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". There was also extensive discussion of new and existing "twinning" programs, through which a Southern institution establishes a two-way link with a Northern institution. Gerald Keusch, for instance, described a new experiment being conducted by the Fogarty Center and the U.S. National Library of Medicine to twin Northern journals with African journals in the area of biomedicine. Such twinning arrangements could help disseminate expertise in editing, peer review, business and subscription management, and also provide a forum for publishing full reports of North-South collaborative projects.

There was great enthusiasm for the kind of scientific twinning arrangements described by Kerri-Ann Jones. "I really think a major impact will come from lab to lab partnerships. Link up two labs to do a three to five year research-based project, and within that project you move everybody –graduate students, post-docs and the faculty members– back and forth. And I think two important things are achieved. First, you give everything a context, you're not putting an individual out there on their own and asking them to plug back into their institution. Second, you are creating a long-term collaborative relationship."

Another great value of such project-oriented partnerships is their focus on scientific and interdisciplinary approaches to problem-solving, the most fundamental aspect of scientific research yet the most difficult to teach in an abstract academic setting. Ida Nicolaisen described twinning arrangements between Danish universities and institutions in Malaysia and Thailand that were devoted to specific issues in waste management and water resources. "Students from the Western world and the developing world went out and worked together, and the real eye-opener for both sides was that the whole point of departure was problem-solving... how to look at and work on a problem in a scientific way." Such twinning arrangements are a relatively new and powerful idea, said Ernst-Ludwig Winnacker (Deutsche Forschungsgemeinschaft [DFG], Germany) "for scientists and students who can link together, have joint experiences, and come to understand each other and how science really works".

In addition to such innovative bilateral approaches as twinning and sandwich programs, Mohamed Hassan described successful "triangular" collaborative models supported by TWAS. In triangular models, a relatively advanced laboratory joins with both a laboratory from a mid-level developing country and a laboratory from a least developed country (LDC), in which support for research equipment and other infrastructure is directed towards capacity building in the LDC.

Especially important are multilateral approaches to support, such as centers of excellence designed to help train scientists from the developing world –centers for which Trieste has provided the world's model.

"The bilateral approach is very beautiful, and there are many good examples" of such successful partnerships, said Arturo Falaschi, director of the Trieste-based International Center for Genetic Engineering and Biotechnology (a sister ICGEB unit is housed in New Delhi), which provides a center of excellence for research and training especially tailored to the needs of developing countries. At the same time, said Dr. Falaschi, "the multilateral approaches [optimize] the conditions whereby the countries who need science most can grow most, can have [their young scientists] trained and then returned to their home countries".

Moreover, as discussed in the next section, emerging Centers of Excellence in developing nations can serve not only their home countries, but as propagating centers for advanced sciences in entire regions of the developing world.

5 • Centers of Excellence should also be Centers of Dissemination

In China, India, Brazil, South Africa and other mid-level developing countries, national Centers of Excellence in the life sciences can also serve as regional centers of training, and as loci around which research collaborations and informal networks can be organized. Importantly, such South-South exchanges are less likely to lead to brain drain than North-South exchanges; students and participating scientists are much more likely to return to their home countries. Thus a built-in "multiplier" effect can be gained by investing in developing world Centers of Excellence that also serve as regional disseminators of life science training and cutting-edge knowledge. "There is a natural ripple effect achieved by supporting [Centers of Excellence] in mid-income countries", said Julia Hasler of UNESCO, "which we see in applications by research fellows from less developed countries seeking to go to mid-level countries".

Such Centers of Excellence and the leading scientists within them also serve as national and regional models –as "lighthouses", said Ernst-Ludwig Winnacker, "which can

really spread ideas and carry the flame of progress" in a way that is visible in a local and regional setting.

Participants at the Trieste meeting all firmly believed that such Centers of Excellence should whenever possible be intimately connected with universities. In this way scientific research and education within a country and region are closely interwoven; a country's most talented students benefit from working with a country's most talented scientists, and vice-versa. Participants thus strongly endorsed what might be called the "Howard Hughes Medical Institute model" of creating a virtual network of outstanding laboratories housed within different universities, rather than the "Max Planck Institute model" of creating clusters of such laboratories in physical centers separate from and independent of universities. This recommendation applies also to developed countries, but is particularly important for developing nations. As the Interacademy Council report *Inventing a Better Future* states: "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". Ongoing efforts in such countries as China and India to more closely link Centers of Excellence with universities are encouraging signs that this conclusion is permeating developing societies.

6 • Life Science Research Networks in the Developing World

Life Science researchers in many developing countries, especially in those with relatively small numbers of investigators, often feel isolated from the rest of the scientific community, lack a critical local mass of scientists in their field, and lack funds to attend international meetings. Yet scientific research thrives on close and dynamic human interactions; on the cross-fertilization of ideas and techniques; on the exposure of new conclusions and methods to vigorous criticism by scientific peers. Fostering such human interactions, not only through Centers of Excellence but through academies, associations and virtual networks, must be a core component to seeding and nurturing life science in developing regions.

Moreover, such organized scientific groups can play a central role in integrating science into government policies and the thinking of business and industry leaders. Groups of developing region scientists linked in associations or academies, said Mohamed Hassan, "can act as a critical force working in developing countries to promote life sciences", and as a source of "independent and objective advice to their governments on scientific issues of national and global concern". Existing science academies in developing nations are increasingly linking into networks to discuss and develop strategies to problems of common concern: this is an approach announced early in 2004 by the member states of the Organisation of Islamic Conference (OIC) in the creation of the Network of Academies of Sciences in OIC Countries. In addition, such scientific associations and academies, when of high quality, can serve as a valuable resource for donor agencies "seeking to identify priorities and come to grips with the real problems on the ground", said Ranjan Ramasamy.

Participants at the Trieste meeting, however, expressed widespread concern about the quality and vitality of national science academies in many developing nations. Membership in such academies can often be more a consequence of political patronage than scientific accomplishment; and memberships are often too heavily skewed towards older scientists far removed from direct contact with research at the laboratory bench. Thus the recent $20 million grant by the Bill and Melinda Gates Foundation to transform and build science academies in Africa is an extraordinary development. This grant, to be distributed through the U.S. National Academies, will help train African staff and scientists to organize research projects, networks and conferences, and to more effectively interface with their own government and with outside funding agencies. One solution to African nations and other developing countries with small research populations or ossified science academies, said Mohamed Hassan, is to form independent regional associations that include leading regional scientists. A web-based life science information network could serve as a platform promoting such regional associations.

The International Brain Research Organization (IBRO), which aims to bring modern neuroscience to developing countries, is organized in such a regional fashion, said Torsten Wiesel, and could serve as a model for other areas of the life sciences. IBRO has regional committees in Africa, Latin America, the Far East, the Near East and Eastern Europe. Well-subscribed regional summer courses are organized, taught in some cases by regional experts and in others by Western scientists. There are grants for students to travel to international meetings, and a web-site providing Neuroscience learning courses freely available to students. All these activities are coordinated by a small,

two-person Paris office, said Dr. Wiesel, "and it makes it possible for neuroscientists all over the world to have a sense of community. I think this is a model that can be used as we think about international cooperation in education and research".

Another important regional model for life science networks described at the Trieste meeting is the Latin American Network of Biological Sciences [RELAB], established almost three decades ago with 15 member countries. "RELAB has functioned as a forum for reflection and discussion of the major problems and opportunities for the life sciences in Latin America", said Jorge E. Allende Rivera. RELAB organizes training courses, workshops and symposia; supports short-term fellowships; and has been an integral component in several regional research and training programs such as those in genomics and molecular virology. Through the aegis of the ICSU, RELAB has served as a model for the creation of similar biological networks in Africa, Asia and among Arab countries.

Critically, students and young scientists are strongly represented in networks such as IBRO and RELAB. The U.S. system of national scientific funding, centered on investigator-initiated proposals and coupled with wide opportunities for scientific independence for young scientists at the most fertile stages of their careers, is recognized as the gold standard for promoting scientific innovation and creativity. Regional networks such as RELAB can help give visibility to a region's young scientists and help them obtain support from local sources or outside donor agencies. In 2005, RELAB will sponsor a symposium, "A Young Scientist's Vision of the Frontier of Biology in Latin America". Three previous symposia in the RELAB series were published, said Dr. Allende. An additional function of the proposed Life Science Web for Developing Countries could be to serve as a forum for electronic publication of such life science-related proceedings from developing regions once they exist in written form.

Another good example of a regional partnership is the International Cell Research Organization (ICRO), represented at the meeting by Ernesto Carafoli. ICRO was set up as a non-governmental organisation by UNESCO in 1962 to assist UNESCO in the implementation of its cell biology program and currently collaborates with the ICSU to bring modern research methods to developing countries. Thanks to this partnership and a collaboration with EMBO, ICRO has been able to make a substantial contribution to the training of younger cell biologists in many regions of the developing world.

7 • Small Grants and Seed Projects

Vincent Alibu presented the remarkable story of Uganda's Med Biotech Laboratory (MBL). MBL is a private biomedical research initiative founded in 1995 by Thomas Egwang, a Ugandan citizen trained as a molecular biologist in the U.S., Canada and Uganda. MBL's primary mission is research on malaria and other regional diseases. With support from WHO, TWAS, HHMI and a host of other outside donor agencies and scientific organizations, MBL has been able to establish research links with a number of national and international facilities; to engage in sandwich M.Sc. and Ph.D. programs with Western universities; and to join forces with a Japanese group testing malaria vaccines, and with a U.S. biotech firm engaged in bioprospecting for novel restriction enzymes. "The MBL, even if small, is a shining example of how more things might be done in the future", said Mary Phillips after Mr. Alibu's presentation. Said Julia Hasler: "... maybe in Africa these private initiatives can be a seed for something greater".

Mohammed Hassan spoke of TWAS's program of direct support for young individual scientists and research groups in the life sciences through merit-based research grants of $10,000 to $20,000. These grants, administered through an outside commission of reviewers, focus on Africa, LDC's and economically hard-hit countries such as Argentina and Chile. "There are many young scientists working in very hard conditions", said Dr. Hassan, for whom even a small grant can mean the difference between conducting and not conducting research.

In addition, said Ida Nicolaisen, there may be a role for donor agencies in providing consultation and seed money for developing world researchers and groups "who may be very gifted but who need some help in designing projects" and in formulating proposals for funding agencies. "This is something that major funding agencies rarely do, but that small private agencies could work on." In this context, Ernst-Ludwig Winnacker spoke of funds provided by the DFG for German scientists to travel to a developing country to talk to local scientists, find problems of common interest and formulate research projects. The Life Science Web for Developing Countries could again provide a service by lending visibility to such small seed projects and individual scientists, and by linking them to potential sources of support.

8 • Emphasizing High-Quality Science

In 2005, HHMI will award 80 scientists from the Baltic, Eastern and Central Europe, Russia and Ukraine with five year grants of $50,000 to $100,000 annually, aiding countries in these regions to retain their most talented scientists and to build scientific capacities. In selecting these new awardees, Jill Conley said that HHMI will employ the same emphasis on quality that characterizes its renowned programs in the United States and around the world, identifying the most creative and innovative scientists and providing them with resources to push the frontiers of the life sciences.

"Whatever we do in [developing nations] must be driven by the quality of the science", said Kerri-Ann Jones. "Different donor agencies and science agencies may have different mandates, but I think we must be united in our commitment to quality." Programs may be designed to support scientists within a given region, said Hans Hagen, but within a given region, there should be merit-based competition and rigorous assessment of quality.

And while the Trieste meeting focused on donor agencies, participants anticipated the conclusions of the recent Interacademy report's recommendations on national strategies for building Science and Technology (S&T) capacity in developing countries: that each nation develop its own strategy reflecting local priorities; that each nation commit a minimum of 1-1.5 percent of their GDP on S&T capacity building; and that resources be allocated through competitive merit reviews with a strong emphasis on quality as well as local relevance.

9 • Digital Libraries of the Life Sciences: Improving Access to Publications and Scientific Information

Scientists and educational and research institutions in the developing world often suffer from a lack of access to journals, databases, textbooks and reference materials. It was to address this problem that The International Network for the Availability of Scientific Publications (INASP) was established in 1992 by ICSU to enhance the flow of information within and between countries, especially those with less-developed systems of publication and dissemination. In facilitating the acquisition of full-text online journals, current-awareness databases, and document delivery, INASP has been working with individual publishers, "packagers" of information, and consolidating subscription agents. The goal is for resources available through the Program for the Enhancement of Research Information (PERI) to be affordable, so that their acquisition is sustainable in the long term. INASP has been successful in negotiating differentially priced countrywide access licenses at discounts of 90% to 98%.

Today, digital libraries of science can be made available to any laboratory or schoolroom with an Internet connection. Already, many life and medical science journals are making freely available all papers six months after publication. Moreover, there are new and existing programs specifically targeted to providing free and open access to scientists in developing countries. Participants at the Trieste meeting agreed that such programs should be expanded to meet the goals enunciated by the Interacademy report: "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 a modest cost, to scientists and engineers from developing nations."

The creation in 2001 of SciDev.net[5] , described by Ellis Rubinstein in his remarks on the rapidly changing international landscape of scientific publications, has provided a valuable new information resource that gathers news, opinions and summary "dossiers" for scientists, educators, journalists and policy-makers interested in how science impacts economic and social issues in developing regions. SciDev.net collects articles and links to material related to specific topics such as genomics, intellectual property rights, and genetically modified food. Science and Nature magazines provide free access through SciDev.net to news items related to developing world issues, and there is close coordination with the TWAS website. Sci.Dev.net is also building regional networks of individuals and institutions who are seeking to give more voice to scientific concerns and viewpoints in their countries and communities. Along with sites such as TWAS, Science NextWave, the New York Academy of Science's "Science Without Borders" and others, SciDev.Net is a welcome sign of increasing attention being given to promoting science in the world through web-based resources. The OpenCourseWare program at MIT, whereby nearly all the teaching material used for MIT undergraduate and graduate courses is available free on the Web, is serving as a model for other universities, and has as one of its central goals the dissemination of knowledge to developing nations.

At the same time, said Ranjan Ramasamy, an "Inverse Knowledge Gap" exists whereby important and valuable information being generated by developing world scientists

5: http://www.scidev.net/

fails to make its way to developed world researchers. "The North doesn't know what the South knows", said Dr. Ramasamy, "and what we have as a consequence is the neglect of some good work, for instance work published in journals in Eastern Europe and in some developing countries like India". In addition, ignorance of developing country life science publications and knowledge can lead to costly errors in the granting of patents –for instance, for the use of turmeric in wound healing in the United States. In areas such as climate change, geology and oceanography, the ICSU has worked for many years to promote interactions between developing and developed world science. "This has proved quite successful in coordinating international research in terms of building up an overall picture with benefits flowing to the whole international community."

Currently, a number of local journals that publish quality research are not covered by ISI and other international indexes, often for financial reasons. Moreover, many local journals often lead precarious and short lives because of lack of sustained funding, effective business plans and publishing expertise. The ICSU, through INASP, has created the Program for the Enhancement of Research Information (PERI) to tackle these challenges, and support capacity building projects in most regions of the developing world. In particular, PERI supports the establishment of on-line services to propagate local research papers globally, and has recently helped organize African Journals OnLine (www.inasp.info/ajo). "I think we need to think about strengthening these kinds of efforts internationally [within the life sciences]", said Dr. Ramasamy.

"Science is universal", said Arturo Falaschi. "If a local journal has good work, say on biodiversity, or one that concerns another important biological problem, why should it not be of universal interest? That is typical of science: you may find something new in a very small place, but it turns out to be of universal interest... I think we now need to utilize this revolution of electronic information to make such new knowledge available world-wide, still maintaining a peer-review system". It was also agreed that English is now the universal language of science, the "Latin of the 21st century", and that local research publications must be written in English if they are to have a chance of being read widely.

In accordance with the goals of creating Digital Libraries of Science available worldwide, special emphasis should be given to providing leading research centers in the developing regions with high-speed satellite Internet access. Major "hubs" for sharing digital information should be organized on a regional basis, based at universities and research institutions whenever possible. In a wired world, the value of such electronic linkages to developing region scientists has many dimensions. A February 2004 Nature editorial stated, for example, that "scientists in the few African laboratories that have [high-speed Internet access] report not just greater access to information and better networking with colleagues, but vastly greater success in applying for overseas grants because they are more up to speed".

10 • Globally Linking Scientists and Projects to Possible Partners and Sources of Support

The Anglo-French Tropical Medicine Information Service can serve as a prototype for a more general web-site describing support programs for developing world scientists working in the life sciences. The proposed Life Science Web for Developing Countries could serve to disseminate information about opportunities not only between Northern donor agencies and scientists and institutions in the South, but within developing regions themselves. Julia Hasler described how she had been unaware of the existence of a well-financed initiative promoting research collaborations between the University of Capetown and scientists in less developed African countries, despite her position as Professor of Biochemistry in Zimbabwe, where the initiative had been presented to university administrators. Dr. Hasler only learned about the initiative when she visited Capetown for other reasons and heard about it from a Capetown colleague. Through benign neglect and a lack of communication channels, "Information is not trickling down", said Dr. Hasler.

"We need to think about how to infuse information about these programs at a lower level", to working scientists themselves, said Joe Harford, so that scientists are aware of potential partnerships and funding opportunities. The Life Science Web for Developing Countries could be a major new step in meeting this goal. In addition, donor agencies in the North, and university and government officials in developing nations, need to address other "software" issues. Charles Gardner (Rockefeller Foundation, USA) remarked that while Offices of Sponsored Research are part of nearly every U.S. research university, "in my experience I have never seen [such an office] in a developing country I've been involved in. This is an office whose job it is to scan the globe for potential funding sources and to

highlight those that may apply to specific researchers at the institution. When we as funders think about raising capacity [in the life sciences] in developing countries we tend to focus on training, and providing equipment and other 'hardware issues', and not to think about such 'software' management issues".

By giving visibility to existing support programs, a Life Science Web for Developing Countries could serve to highlight complementary opportunities for funders and donor agencies with complementary guidelines and priorities. "The [U.S.] National Science Foundation cannot pay for infrastructure abroad", said Kerri-Ann Jones. "But [through partnerships and collaborations] the NSF can say, this lab in a developing country is really good, we'll put more Americans there to work on this important research topic, and in order to do this they may need X piece of equipment... We need to develop more creative partnerships with the donor community and be an advocate for explaining the role of science in development."

11 • Highlighting Success Stories and Shining Examples

There was wide agreement among participants at the Trieste meeting that the careful crafting and dissemination of "shining examples" or "success stories" of science at work in the developing world should be a major mechanism for promoting science in developing nations. Human beings, whether senior scientists or young students, communicate with one another through stories. And stories about life scientists operating in real-life developing world contexts can be adapted to different audiences, said Joe Harford, so that "best practices can be elevated to attention both within the scientific community, and with the public and policy-makers".

When TWAS began to organize thematic networks of excellence in the South to address specific areas such as safe drinking water, medicinal and food plants and dryland biodiversity, said Mohamed Hassan, the first thing TWAS asked of participating institutions was that they "describe a successful experience where science and technology was developed in that institute and used to solve a particular problem". Thus such success stories played a crucial early role in the scientific development process itself, by helping introduce institutions and scientists in newly-formed regional networks to each other. TWAS published a number of such case studies as monographs. Such relatively technical publications can then serve as the basis for brochures and other media to reach a wider non-scientific audience.

"We've become very, very involved in the publication of success stories", said Peter O'Neill of the UK's Department of International Development. "Even within our own organization it's unclear at times what has been done and how and by whom." These success stories can serve to help elevate practices within a donor agency itself. Moreover, said Dr. O'Neill, "a major part of being able to influence people is being able to convince them that what you've done in the past has had a positive outcome". Yet such success stories and shining examples also must be carefully crafted. Optimally shaping such stories so that they are comprehensible, humanly-interesting and will reach their intended audience is "almost a research program in itself", said Dr. O'Neill.

The Life Science Web for Developing Countries could gather and provide links to representative examples of such well-crafted success stories, including digital video presentations that have perhaps the greatest potential for making the practice of science immediately vivid to a wide audience. Such success stories, whether written or on video, should be presented from a range of perspectives. Some could be project-oriented, emphasizing how local problems are being addressed by scientific methods by teams of scientists from South and North alike. Others could be more biographically-oriented, offering profiles of the life stories and career paths of individual men and women, of representative developing world researchers and students in the life sciences. Such biographically-oriented profiles could form a collection of human stories to which non-scientists can relate, and of "virtual" role models for young people interested in science.

One example of such a story was provided by the Trieste participant Vincent Alibu, mentioned previously, the son of a policeman who began his scientific research career at the MBL in his native Uganda. There were no scientists in Mr. Alibu's family or circle of acquaintances. Yet as a child Mr. Alibu had an intense curiosity about the nature of the living world, an expression of the "biophilia" that the great entomologist E.O. Wilson has proposed to be a constitutive component of the human mind. As a university student in Uganda, Mr. Alibu saw on a bulletin board an advertisement for research opportunities at the MBL. Answering this advertisement brought Mr. Alibu directly into a local branch of the global "Tree of Science". Once he entered this branch, Mr. Alibu could eventually travel from Uganda to pursue advanced studies of the universal science of molecular biology at Stanford University and the University of Heidelberg, where he is now a Ph.D.

student, working to fulfil his dream of returning to his home country to conduct malaria research. Indeed, the universal language and techniques of molecular genetics and biology are transferable from place to place, from problem to problem. Like life itself, the languages and techniques of the life sciences are marvellously adaptable to local challenges; like life itself, life science research is woven from a host of fundamental themes with infinite variations.

The collection of shining examples and success stories should be a major mechanism for communicating the culture and value of life sciences in developing nations, and for disseminating knowledge of best practices within a given developing region. Mohamed Hassan described major recent investments in biotechnology in Nigeria, for instance, and how such investments can spur parallel investments in neighboring countries. "Shining examples are very important", said Dr. Hassan, "because countries emulate one another. If one country sees another doing very well, they now want to know why they are doing well". Such knowledge of best practices can also help governments refine and optimize their scientific research and education policies to make them more attractive to donor agencies. "The selection pressures are everywhere the same", said Hans Hagen. "You have to drive your economy up, you have to train a well-educated work force." Donor agencies will naturally prefer to invest in countries with sound and responsive government and business leaders and management policies.

The Life Science Web for Developing Countries could serve as a virtual bulletin board offering stories for young men and women across the developing world who, like Vincent Alibu, are interested in joining the Tree of Science, in learning and applying the global language of life to local problems.

12 • Communicating the Culture and Value of the Life Sciences to all Levels of a Developing Society, from Parents to Politicians

"Sometimes science has been presented as a kind of dessert", said Frank Gannon, something a developing society may have after "the main course... [after] the development of infrastructure, roads, health care and housing. But science has to be much more mainstream... and we absolutely need to have education [about the value of science] at every level". Scientists need to be seen, said Dr. Gannon, as the "landing docks" enabling such scientific advances to get a foothold within developing societies, and as the "crystallization points, the growth points" from which the fruits and culture of science can radiate outward through these societies. Moreover, said Dr. Gannon, much greater efforts must be made to educate the large proportion of students who will not themselves become scientists "not just about science, but about the scientific process. People need to understand how we [in the scientific community] can disagree and yet still converge on truth".

"The medium for scientists to get information out to the general public is the press", said Gerald Keusch, "and scientists need to do a much better job in engaging with the press". Indeed, this problem is endemic to both the developed and developing nations. "In Europe, the idea [that much of the general public has] that eating genetically modified food is going to change your genetic structure is absolutely a failure of scientists to communicate effectively."

The scientific process, in which ideas are subject to passionate, yet rational and empirically-based test and debate, served as the paradigm for the Open Society described by the philosopher Karl Popper. The pursuit of scientific knowledge has long stood as a leading embodiment of the values of intellectual freedom and honesty. In keeping with these values, it is important that interactions between the developed and developing world in the life sciences be true partnerships, conducted ethically, with fair allocation of profits and other potential rewards, and with respect for the value of indigenous resources and practices. Seedling "Trees of Science" can only take root in societies that feel some sense of ownership of the scientific projects being pursued, and a sense of fairness in how such projects are carried out.

Conclusion

In 1950, at a time of increasing political and military tension around the world, the physicist Niels Bohr published an Open Letter to the United Nations whose words remain deeply resonant today. "Proper appreciation of the duties and responsibilities implied in world citizenship is in our time more necessary than ever before. On the one hand, the progress of science and technology has tied the fate of all nations inseparably together, on the other hand, it is on a most different cultural background that vigorous endeavors for national self-assertion and social development are being made in the various parts of the globe."

In 2004, as in 1950, scientists have the opportunity to play a leading role in promoting productive interchanges across deep cultural, political and geographic divides: for scientists are the pre-eminent global community of our era. Yet the scientific and technological culture of the 21st century is failing to reach most of earth's people. As the IAC report "Inventing a Better Future" concluded: "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..."

Participants at the Trieste meeting fully endorse the IAC study panel's recommendation to create two major new global funds for science: A Global Institutional Fund to provide five to ten years of support to some twenty centers of excellence in developing nations; and a Global Program Fund, set up along the lines of the Human Frontier Science Program, "for creating new partnerships with advanced research institutes, [which] should be established as a competitive grants system... in which international referees would review the quality of the projects being proposed by various centers of excellence in developing nations. Preference would be given to proposals that involve groups in several local and regional institutions". Torsten Wiesel described such major new global investments in developing world science as the modern equivalent of the post-World War II Marshall Plan for the rebuilding of Germany, Japan and other nations. "The Marshall Plan was the best investment the U.S. ever made", said Dr. Wiesel, "lifting the entire world economy. We have to have a world view, and see that the have-nots of the world have access to knowledge and technology". Thus such developing world investments are not only motivated by humanitarian concerns; they make sound economic and security sense.

Of course, negotiating agreements for how to fund and disperse these new global funds will take time and concerted effort. In the immediate present, participants at the Trieste meeting strongly recommend the creation of an Internet-based Life Science Web for Developing Countries. This could serve as:

- **a central information source describing funding opportunities and partnerships available for life science students, researchers and institutions from developing nations**

Given interest and additional resources, it could add additional features, including serving as:

- **a central information source for life science students, researchers and institutions in developing regions to place "advertisements for themselves", describing their projects and goals, and the kind of support and/or partnerships they are seeking**
- **an initial contact site for life scientists seeking to form research networks and associations within a given region**
- **an initial contact site for the scientific "diaspora" of a given developing nation who are seeking to expand their connections to their homeland**
- **a collection point for well-crafted success stories and shining examples, in both written and video form, of life science at work in developing regions and of profiles of representative scientists and students**

This Life Science Web for Developing Countries could provide a much greater degree of coordination between donor agencies; give both local and international visibility to recipients and help match them with possible sources of support; and evolve into a multi-faceted international resource for promoting life science education and research that could serve as a model for other areas of science and technology.

This virtual web site also could aid local and regional scientists and advocates in their efforts to make science education and capacity building a central priority of national and local government and industry. The argument that must be made to politicians and business leaders, said Arturo Falaschi, is that "if you want to break the vicious cycle, the most cost-effective way is through science funding because it does not require that much money [relative to other infrastructure development costs], and you can really have a big amplification [of your investment]. Not in time for the next elections, perhaps. But after all, if you don't plant trees, you're never going to get any fruit. And people have been planting trees for many years".

The inborn impulse to understand nature, out of pure curiosity and for the benefit of humanity, exists among all people. The Tree of Science has its deepest roots in the universal spirit of the human mind. And as history has shown, the happy collateral benefit of this curiosity is the transformation of economies, technologies, and health care systems. At Trieste, participants saw that in spite of daunting challenges, the seeds of this Tree of Science lie latent and germinating in many developing regions of the world. Indeed, the burgeoning of even one high-quality science research center within a developing nation can serve to jumpstart a scientific field, catalyzing its own growth by attracting some of a nation's brightest young minds to scientific careers. Local centers of excellence in countries such as India, South Africa and China are already proving to be centers of scientific dissemination within developing regions, acting as central "trading zones" where the culture and fruits of the life sciences can be seeded throughout the area through regional education, training programs and collaborative research projects. In developing countries with these centers of excellence, participants in the Trieste meeting described how knowledge gained from the amazing global advances in our understanding of living processes is being applied to local medical, agricultural and ecological challenge, and to promote economic development. Our goal must be to take a concerted series of initiatives to help create a world of scientists who "act locally, but think –and interact– globally", to thread and weave rich, and ever-evolving webs of interactions joining life scientists from developing and developed regions around the world. As Niels Bohr concluded in his 1950 Open Letter to the United Nations: "every initiative from any side towards the removal of obstacles for free mutual information and intercourse would be of the greatest importance in breaking the present deadlock and encouraging others to take steps in the same direction".

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