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Scientific Collaboration – Promoting Progress, Building Bridges

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Abstract – International scientific collaboration and co-operation can accelerate the progress of science, help build bridges between diverse societies, and foster the development of science and technology in non-industrialised countries. This is possible because science is a common language (although the progress of science is often influenced by non-scientific factors). This paper gives examples of the role that scientific collaboration can play in bridge building and in conflict resolution. A proposal is then presented for "Bridge-building Fellowships" which would contribute to strengthening scientific capacity in developing countries by helping to stem the brain drain and providing a basis for collaborations with scientists in industrialised countries.

Introduction

The laws of nature are the same everywhere in the world (indeed everywhere in the universe, and always have been, as far as we can tell from light reaching us from distant galaxies). Thus (*pace* cultural relativists[1]) science and the scientific approach, which acknowledges nature as the ultimate arbiter of argument, constitute a common language. Scientific work therefore lends itself to international collaboration. It is also the case that many problems with scientific or technological dimensions do not respect national boundaries and need collaborative international approaches (eg dealing with diseases that air travellers can spread rapidly across the globe, pollution, or fall-out from nuclear accidents).

On the other hand, the way science progresses is influenced by scientific fashion, and conditioned by the social interactions of scientists with each other and with society as a whole (to this limited extent cultural relativists have a point). Moreover, the agenda for scientific research tends to be set in industrialised countries. Thus while malaria accounts for three per cent or more of the world's disease burden,[2] it attracts less than two-tenths of one per cent of investment in biomedical research. Would this be the same if malaria were prevalent in North America? Even when funding is not an issue, the fact that scientific prestige world wide is largely related to publication in European and American journals, and must attract the interest of first-world reviewers, biases what research is done everywhere.

Furthermore, when scientific understanding is incomplete, and/or the issues are so complex that additional assumptions are needed (eg in the case of some environmental issues or climate change), conclusions may be influenced by social or political opinions. For example, during the 1958 Comprehensive Test Ban Treaty negotiations, an attempt to separate technical and political issues

[1] An extreme version of the view that science is a social construct is that "Scientific knowledge is affected by social and cultural conditions and is not a version of some universal truth that is the same at all times and places" - Andrew Ross quoted in the New York Times, 18/5/96, as reported by S Weinberg, in *Facing Up – Science and its Cultural Adversaries,* Harvard University Press, 2001, who has effectively countered this position.
[2] According to Jeffrey Sachs (*New Scientist*, 17/8/02), whose own earlier research showed that malaria may cost one per cent or more of the rate of economic growth in countries in sub-Saharan Africa.

failed. One of the participants[3] has observed that whenever disagreements arose, the Soviet experts argued that verification would be easier, and require less intrusion, than the American experts believed – a polarisation that corresponded to the political interests of the two sides.

The fact remains that science is a common language. And scientific collaboration can not only accelerate scientific progress, but can help create bridges between diverse societies, and play a role in mitigating conflict, building on existing scientific networks and the mutual professional respect of the scientists involved. It can also contribute to development. The rest of this paper addresses these themes. It begins with some general remarks about the changing context in which scientific collaboration must be considered, and ends with a proposal for "Bridge-building Fellowships", which would help stem the brain drain and foster effective collaborations with scientists in industrialised countries.

Context

There is a long and beneficial tradition of international scientific collaboration, which is being made easier by the advent of cheap jet travel and high-speed communication systems. On the other hand, national policies for science and technology put increasing emphasis on strengthening the economy and gaining market advantages, and generally there is tension between collaboration and competition. Moreover, since 11 September 2001, protectionist tendencies have increased, and new barriers to international academic exchanges and collaboration have been erected. At the same time maintaining and strengthening personal contacts has become more desirable.

This is not the place to discuss all the pros and cons of collaboration in science and technology, the barriers that it faces, and the different forms that it may take.[4] Briefly, the arguments in favour of collaboration include the need to tap into the best sources of knowledge wherever they are available, the fact that international collaboration may be required to reach critical mass (especially when a multidisciplinary approach is needed), and a desire to share costs (as well as

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3 W Panofsky, in *Scientific Cooperation, State Conflict – The Roles of Scientists in Mitigating International Discord*, ed A L C de Cerreno and A Keynan, New York Academy of Science, Vol 866, 1998.

4 For a discussion, especially of the situation in "big science", see C H Llewellyn Smith, *European Review* Vol 7, No 1, 1999.

bridge building and promoting development). These arguments are especially cogent from the perspective of small and scientifically weak countries.

Various changing factors are affecting the nature of scientific collaboration. On the one hand, the increasing cost of much scientific equipment, and the importance of fostering interdisciplinary collaboration, are leading to the increasing concentration of much experimental research in centres of excellence. On the other hand, the Web allows the creation of dispersed "virtual communities" in many theoretical sciences.

For example, in the case of my own field of theoretical physics, it was until recently highly desirable to work at a leading centre, in order to be able to talk to collaborators and have access to the latest ideas, often only available in selected circles in pre-print form. Today, the latest pre-prints are instantly available on the Web, and collaborators can interact daily over the Internet (although unfortunately adequate Internet access is still by no means universal). In some fields, as we shall see when considering CERN, cheap international travel together with the Web allows dispersed communities – including some in developing countries – to collaborate in experiments at distant locations also.

Another relevant trend is the increasing blurring of the boundaries between university-based research and research and development in industry. In the past, science-based technological research – in industries such as pharmaceuticals, electronics, computers and aeronautics – was mainly carried out in industrial laboratories. Universities concentrated mainly on basic research. This has changed over the last two decades.

Science-based industries today need to draw on a much wider range of research skills and knowledge than can reasonably be provided in-house, and the mixture of necessary skills can change very rapidly. For example, developments in communications systems need input not only from electrical engineering and computer science, but also from psychology, economics, ergonomics and physiology. These disciplines co-exist in universities, where industry can tap into them. The boundaries are also being blurred by the fact that universities are increasingly involved in technology transfer and the creation of spin-out companies (not only in Europe and North America, but also for example in China, where science parks are associated with a number of leading universities).

These trends may have a detrimental effect on collaboration as university groups and their industrial partners put increasing emphasis on protecting intellectual property. On the other hand they strengthen the case for focusing on universities in building scientific and technological capacity in non-industrialised countries, a subject to which I return later.

Building Bridges: Lessons from CERN

CERN, the European – now effectively world – Laboratory for Particle Physics, is the world's largest collaborative scientific enterprise.[5] Despite some very special features, CERN's experience provides generally valid illustrations of the scientific value of collaboration, its role in building bridges, and the fact that collaboration can allow small groups in remote universities to participate effectively in world-class science.

Some 6,500 scientists come to CERN from universities and research institutes in over 50 countries to carry out research – see the appended map of the distribution of CERN-users (CERN's own staff includes only some 90 research scientists, who work in collaboration with external users). Note first that CERN has effectively become a world (or at least a northern hemisphere) organisation, and second that although most of the users are based in industrialised countries, significant numbers come from countries in transition and developing countries. The users typically spend a third of their time at CERN. They include some 900 PhD or Diplom students, who customarily spend a year or more at CERN during their studies.

CERN constructs and operates large accelerators designed to smash particles of matter together in order to study their constituents and the forces that control their behaviour at the deepest level possible. The points where the particles accelerated at CERN are brought into collision are surrounded by giant detectors, packed with high-tech components, that record and analyse the debris of the collisions. The size of these detectors, and of the teams needed to build and operate them and analyse the data, has grown over the years. In the case of the CERN's current flagship project, the Large Hadron Collider,[6] which will be the world's frontier facility for exploring the fundamental structure of matter when it comes into operation in 2007, the two major detectors are as tall as six-storey buildings. The teams of scientists and engineers associated with each of these

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[5] Information about CERN, where I was Director General 1994-98, can be found at **http://www.cern.ch**.

[6] For an account of the LHC see C H Llewellyn Smith, *Scientific American*, July 2000 (updated version to be published in a special edition, "The Edge of Physics", February 2003).

two detectors already number over 2,000, based in over 150 institutes in some 40 countries.

The elements of the detectors are generally constructed by the users in their home institutions or countries, frequently in collaboration with local industry, before being brought together and assembled at CERN. This ensures the maximum involvement of the users, and also facilitates technology transfer. Likewise much of the data analysis is carried out off-site.

The pluri-national collaborations that construct the detectors and carry out the experiments constitute a cultural and political experiment, as (see below) envisaged and wished by the founders of CERN, and also a management challenge. In response to this challenge, Tim Berners-Lee conceived the idea of the World Wide Web as a means of sharing information between groups that collaborate at CERN,[7] at a time when the size of the collaborations was growing from tens to hundreds of scientists.

CERN, which formally came into existence in 1954, was conceived in the late 1940s when two separate ideas coalesced. First, European physicists interested in the fundamental structure of matter realised that no single European country had the resources to compete with the Americans in constructing large accelerators, and that joint facilities would therefore be essential. Second, these scientists and a group of far-sighted diplomats and scientific administrators conceived the idea of creating a joint European laboratory as a contribution to rebuilding bridges between nations that had recently been at war.

Scientifically CERN has certainly succeeded, and collaboration at CERN has now moved from a European to a world scale in response to the growth in the size and complexity of the facilities that are needed to make progress in particle physics. CERN has demonstrated the power of collaboration between scientists from different backgrounds, which can generate added scientific and technical value. Groups of scientists or engineers from (say) France, Russia and the USA, who have been trained to approach problems in different ways, can come up with

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[7] See J Gillies and R Cailliau, *How the Web was Born*, Oxford 2000. The Web was proposed in 1989. The Internet (ie the network of wires on which the Web operates) was created much earlier. But while emails were relatively easy to send and were in use in many scientific communities pre-Web, the transmission of files over the Internet required knowledge of the recipient's computer, and general sharing of information was impossible. Use of the Web moved beyond CERN in 1991, beyond particle physics in 1992, and beyond scientific communities in 1993.

very original solutions that they might not have found separately. Furthermore, participation in CERN has helped the development of science generally in some scientifically weaker countries by introducing international standards and the idea of international peer review of national research programmes.

To participate in pluri-national collaborations at CERN is an enriching experience for the scientists and engineers involved, especially for the students, many of whom move on from particle physics to other careers, taking with them an enhanced knowledge of other cultures and societies (and also splendid networks of international contacts, and a good knowledge of French and English). Indeed, generally CERN has done much more than simply produce outstanding science. For example:

- CERN was the first inter-governmental organisation to which Germany was admitted, as an experiment, after the war.

- Other European scientific organisations were modelled on CERN[8] (several were housed initially at CERN until they found permanent homes).

- The first post-war contacts between German and Israeli scientists, outside international conferences, were made on the neutral territory of CERN.

- CERN kept open scientific relations with Russia and other east-bloc countries during the Cold War. Not only did Russian scientists work at CERN, but in the late 1960s and early 1970s CERN physicists were involved in experiments at the accelerator at Protvino, which was then the highest energy accelerator in the world.[9]

- A joint Russia–CERN summer school devoted to particle physics and related technologies was started in 1970 and continues to attract students from across Europe.

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[8] See *History of European Scientific and Technological Cooperation,* European Commission, 1997 (ISBN 92-828-0913-7).

[9] See *Science Bringing Nations Together,* CERN 1998, a booklet produced on the occasion of an exhibition with this title organised at UNESCO by CERN and the Joint Institute for Nuclear Research (JINR) at Dubna in Russia. Interestingly, the first western appearance of the secret military Antonov 22 transporter was at Geneva airport in 1970, when it was collecting equipment to take to Protvino.

- While many Russian scientists moved west after the end of communism, most of the experimental particle physicists felt able to remain, knowing that wherever they lived, their research would be based at CERN where they were already welcome.

- CERN has been closely involved with two organisations (INTAS and ISTC) devoted to sustaining science in the former Soviet Union (especially what remains of some brilliant research groups, eg in physics and mathematics), and providing alternative occupations for scientists and engineers who worked in the weapons programme.[10] INTAS and ISTC provide a model for external funding of science also in developing countries, by working "bottom-up" and funding the scientists involved directly, in response to peer-reviewed applications, in order to prevent the funds being diverted into other channels.

- Inspired by its history, scientists at CERN set up the Middle East Scientific Cooperation Committee, which brought together Egyptians, Israelis, Jordanians and Palestinians (as well as some Europeans and Americans). This led to the idea of SESAME (Synchrotron Light for Experimental Science and Applications in the Middle East), a joint synchrotron radiation laboratory modelled on CERN, which will use components from the Berlin synchrotron (BESSY), donated by Germany. SESAME was established at a ground-breaking ceremony in Jordan on 5-6 January 2003, in the presence of the King and the Director General of UNESCO. So far six countries have ratified the convention (Bahrein, Egypt, Iran, Jordan, the Palestinian Authority, and Turkey). Others are expected to join shortly, including Oman, the United Arab Emirates, Pakistan and Israel. It is going ahead in a good spirit of cooperation under the auspices of UNESCO, with a former Director General of CERN, H Schopper, as Chairman of the interim Council.

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[10] See M Jacob, *The Bottom-up Approach: the Efficient Way to Help Science*, Physics Today, April 1999. A former Director General of CERN, C Rubbia, played an important role in the creation of INTAS (the International Association for the promotion of cooperation with scientists in the new independent states of the former Soviet Union) in 1993. INTAS, which is largely funded by the EU, provides research grants. ISTC (The International Science and Technology Center), which is funded by the EU (40%), the USA (40%) and Japan (20%), was created in 1992, in response to a request from the Russian government, with the aim of reducing the risk of the dissemination of advanced weapons-related technology. It provides funding for joint research and development projects involving former Soviet weapons laboratories and western institutions. CERN and CERN-user groups are partners in a number of ISTC projects. With its long experience of working with east-bloc countries, CERN was able to contribute immediately to the early success of these programmes.

Two important general lessons can be drawn from CERN's experience. First, scientists of many different nationalities and cultures can collaborate successfully and such collaboration has both scientific and political benefits. Second, science can be done on a hub and spoke model that allows the productive participation of scientists based in small universities remote from other centres of scientific excellence. In the case of CERN, where relatively few people are needed actually to run the detectors, which operate for months at a time, and much of the data analysis is done at home off-line, the spokes can span continents. Earlier experience at CERN, confirmed at other European laboratories and elsewhere, shows that a hub and spoke model can also work for experiments that involve small groups and require regular hands-on use of equipment, provided the hub is within a few hours' travelling distance.

Building Bridges: the Role of Scientists in Mitigating International Discord

CERN, and activities spun out of CERN, provide good examples of various ways in which scientific collaboration can build bridges between societies. Many other cases in which scientists have played a more than technical role in international relations were analysed during a conference on *Scientific Co-operation, State Conflict – The Roles of Scientists in Mitigating International Discord*[11] organised by the New York Academy of Sciences in 1998. The cases discussed at the Conference included:

- Government-initiated activities, such as the nuclear arms control negotiations; US–Soviet cooperation in space (which was launched with rhetoric on both sides concerning cooperation as a means of increasing mutual understanding, promoting global solidarity, and diminishing conflict); the International Institute for Applied Systems Analysis (which was proposed by Lyndon Johnson in 1966 as a bridge building initiative[12]); and South American Nuclear cooperation.

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[11] *Loc cit* (footnote 3). See in particular the introductory and concluding articles by A Keynan.

[12] The IIASA, which was formally founded in 1972 and is situated in Vienna, involves a number of countries besides the USA and USSR/Russia. It was judged a scientific and political success initially, but the Reagan administration saw it as a vehicle for spying and ended US funding, which however was restored in 1989. The goal was to bring together scientists from different countries and disciplines to study problems such as pollution, health care and the management of large enterprises, and good work is reported to have been done in a number of areas ranging from agriculture through migration to transportation.

- Scientist-initiated activities, such as scientific cooperation between the USA and China (which was started by individuals in 1964 and did not become institutionalised until 1973); the Pugwash Movement (especially its key role in conceiving and promoting the idea of the International Treaty on Chemical and Biological Weapons); the unofficial and unpublicised contacts between Palestinian and Israeli academics that preceded informal and non-committal exploration of options during an academic seminar in Oslo, which in turn evolved into the official secret diplomatic negotiations that led to the peace accords; and the role of scientific cooperation in normalising Israeli–Egyptian relations (building on a Congressional initiative that provided funding: of programmes in marine sciences, medicine and agriculture, only the latter was judged successful – indeed, exceptionally successful – politically as well as scientifically).

It was noted that in many if not all the instances considered, "bridge building" had been a conscious motive, and it was concluded that the evidence shows that scientists and scientific collaboration can play a constructive role in preventing conflict. Key contributions have included using pre-existing scientific networks to communicate and cooperate across lines of conflict, the development of common frameworks for discussion, providing examples of cooperation in situations in which governments have been unsuccessful, and helping governments by providing vehicles for cooperation, as well, of course, as technical contributions, such as developing mechanisms for verification of treaty compliance.

Promoting Development

There is a widespread consensus that building scientific and technical capacity has a major role to play in development, and that collaboration is one of the keys to capacity building. A typical statement of the arguments[13] is:

13 Taken from literature produced by the Millennium Science Initiative, an American initiative that supports the development of science and technology in developing countries: **http://www.msi-org**. For another exmple, see the synthesis of discussions organised over two years by the Belfer Center for Science and International Affairs and the Center for International Development at Harvard (C Juma et al., *Int J Technology Management*, 629, No7/8, Vol 22, 2001), which begins: "Science and technology are widely recognised as important factors in the economic transformation of developing countries, as well as countries with economies in transition". Juma et al. also discuss fostering innovation, which I shall not discuss here, except to say that the science parks attached to some leading Chinese universities

"Science and technology provide the tools to address local challenges in agriculture, health, energy and other fields, and stimulate economic growth. Developing countries that lack their own experience in science and technology must depend on the strategies, priorities, and personnel of donor nations; in effect, they must import solutions to problems that they themselves are best positioned to understand."

"…each country must develop its own capacity in science and technology to be competitive in the global economy and to apply scientific developments to domestic needs…at least some of a country's researchers should be at the forefront of their disciplines. First, new knowledge drives innovation. Even when a country is concerned primarily with the application of existing knowledge, it gains intellectual rigor by "pursuing the leader" at the forefront of the discipline. Second, knowledge creation stimulates the free exchange of ideas among colleagues world-wide. Countries involved in the production of knowledge are best positioned to use it."

The latter text goes on to refer to expanding linkages with the international scientific community, mentoring graduate students and postdocs, helping to form a critical mass of highly trained researchers, and slowing the brain drain. According to Jacques Gaillard:[14] *"Aiding research in collaboration and in partnership with developing countries is now presented as the principal means of enabling these countries to build problem-solving capacities."*

I subscribe to this consensus view, although it has to be said that it does not seem to be supported by either solid theoretical arguments or empirical evidence. Comparative advantage might naïvely appear to suggest that developing countries would be best advised not to invest in science and technology, beyond developing the minimal capacity needed to import turn-key devices and use technology developed elsewhere. Such a policy would seem, however, to be a recipe for perpetual technological dependency and economic stagnation.[15]

(which act as incubators for enterprises that would not necessarily be regarded as at the cutting technological edge in industrialised countries) may provide lessons for other countries in transition and for developing countries.

[14] *Knowledge and Policy*, 31, No 2 ,Vol 7, 1994.

[15] As David Landes has pointed out (most recently in *The Wealth and Poverty of Nations*, W W Norton, 1998), faith in a naïve version of comparative advantage would have led to Germany remaining a purely agricultural country after the Industrial Revolution started in Britain**.**

While much can be learned from studying selected cases (South Korea and Taiwan versus Mexico and Brazil; India; etc), the circumstances in different countries seem too diverse to draw general conclusions. Similarly, the data tell us little about the relationship between investment in education and future economic growth. Indeed, certain World Bank data seem to show an anti-correlation,[16] and it is difficult to tell whether the undoubted correlation between current levels of investment in education and current GDP is cause or effect.

Nevertheless a certain level[17] of investment in both education and in science and technology is surely necessary to underwrite long-term growth, although it is clearly not sufficient. This, together with the long time-scale involved in reaping the full benefits of expanded education, which may not show up until the next generation, would explain the lack of unequivocal correlations between such investments and future growth. Accepting that investment in education and building scientific capacity are desirable, one must then ask, in what fields, at what levels, and how should it best be done?

While high priority should obviously be given to primary education and the eradication of illiteracy, I believe that building up at least some modest level of high-quality university education is also very important. It is needed, for example, to foster the growth of the middle classes, which is necessary for development. Strengthening universities is certainly essential for fostering science and technology,[18] and vice versa.

The choice of scientific and technological fields should obviously depend on the circumstances in particular countries. As far as it is possible to generalise, it would seem sensible for developing countries to focus on issues of local or regional importance, which may be neglected elsewhere, such as tropical agriculture and diseases, nutrition, the use of natural resources, and particular

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[16] For an interesting discussion see Alison Wolf *Does Education Matter?*, Penguin, 2002. Wolf disposes particularly effectively of the fallacy that public returns from investment in education can be inferred from private returns.

[17] At some level, one would expect diminishing economic returns from investments in science and technology and in education (see A Wolf, *loc cit*, who points out that while being one of the world's most prosperous countries, Switzerland has one third of the average university enrolment rate for the OECD). In particular, the UK government's argument that 50% participation in higher education is desirable on economic grounds does not seem to hold water, although a case might be made on general educational/social grounds.

[18] For a wider discussion of the role of universities see, for example, *Universities and Development*, ed R Bourne, Association of Commonwealth Universities, 2000 (ISBN 0 85143 1720).

local or regional environmental issues. Even when such subjects are studied elsewhere, local expertise is needed when determining and implementing new policies, and for sociological reasons. As the Nigerian journalist Seun Ogunseitan has pointed out:[19] "A Nigerian Professor of environmental sciences is in a better position to explain to a Nigerian audience the dangers of unchecked destruction of tropical rainforests than an American, even if the latter is the world's leading authority on the dynamics of global climate, the ozone layer problem and the greenhouse effect".

I would argue, however, that concentration on issues of particular local or regional interest should not be to the exclusion of support for other fields, nor should all basic research be automatically excluded. Manifestly relevant subjects need underpinning by others, which risk being neglected. In the words of Jacques Gaillard (*loc cit), "…mathematics and the basic natural sciences, which must be developed to a sufficient level in any country in order to support local training and applications in engineering, agriculture, environment and health, are often not included among co-operative projects."* The pace of technological change is such that today's "irrelevant" (basic) subject may be deemed "relevant" (applied) tomorrow (indeed, generally the distinction between applied and basic research is becoming increasingly meaningless). Furthermore, "irrelevant" but glamorous subjects can act as beacons that attract young people into science. I would not argue that developing countries should put significant resources into, say, cosmology or particle physics, but supporting a handful of participants should not be excluded.

The experience of scientists who have tried to work in developing countries illustrates the barriers to fostering a science and technology base. Consider the case of Abdus Salam, the Nobel Laureate from Pakistan who spent most of his career at Imperial College in London and the International Centre for Theoretical Physics (ICTP) in Trieste,[20] which he created. After doing a PhD in Cambridge, Salam took a post in Lahore in 1951. He immediately ran into two major difficulties: lack of regular interactions with his scientific peers, and of access to recent literature. If he had been an experimental – rather than theoretical – physicist, Salam would presumably not even have contemplated attempting to

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[19] In an interview in *The Discipline of Curiosity,* ed J Groen, E Smit and J Eijsvoogel, Elsevier, 1990.

[20] Salam, whom I knew well, has written extensively about his own experience and about science in developing countries: see his collected essays, *Ideals and Dreams,* ed Z Hassan and C H Lai, World Scientific, 1984.

continue his research career in Pakistan, with no real prospect of access to state-of-the-art equipment.

As it was, Salam only lasted three years in Lahore before returning to Cambridge, but he remained passionately committed to helping to build up science in developing countries. He believed that, in view of the difficulty of providing adequate experimental equipment, it made sense to begin with theoretical work (including work in his own "useless" field of particle physics, because of its beacon effect, and because he rightly saw building up science and education as being about more than economic utility). Salam raised funding for the ICTP, which opened in 1964, in order to help theoretical physicists in developing countries. The ICTP has played an important role as a centre that can be easily visited by scientists from developing countries, where they can mix with their peers from both developing and industrialised countries.

Meanwhile the difficulties recognised and encountered by Salam have been partly ameliorated. First, concerted efforts are being made to improve the dissemination of electronic and paper-based information by bodies such as the International Network for the Availability of Scientific Publications (INASP), which facilitates a significant portfolio of activities including a Programme for the Enhancement of Research Information. INASP also acts as advisor to several agencies that promote development such as the Carnegie Corporation and its partners in their important African Public Library Revitalisation programme. Some scientific communities, led by the particle physicists, post all pre-prints on the Web. A wide range of academic literature has been made available world-wide on the Internet, thanks to the creation of JSTOR (Journal STORage*)* by the Mellon Foundation. For a small fee, JSTOR provides institutions in 70 countries with access to back issues of some 300 journals.

Much remains to be done, however. Internet access is still non-existent or inadequate[21] in many places. JSTOR does not yet cover all disciplines, and because the publishers are not willing to cede copyright completely, the journals are generally only available if they are five years old (although some are three or fewer years old, and publishers are coming to understand that even recent back issues have no commercial value). The cost of academic journals (which has

[21] The International Foundation for Science found this to be the case for many of its grantees in Africa – see MESIA Report No 2 on **http://www.ifs.se**. The IFS is involved in one of many projects to support ICT/Internet access in Africa – see B Porter and J Gaillard, paper presented at the Science Council of Japan's International Conference on IT-based Capacity Building, January 2003.

typically been rising 10 per cent pa, or faster for scientific journals) is a major problem in all countries. Perhaps a lesson can be learned from the USA which, during most of the nineteenth century, provided no copyright protection for foreign authors, arguing that it needed the freedom to copy in order to educate the new nation.[22]

Second, it is now possible to interact instantaneously with collaborators and peers all over the globe wherever Internet access is adequate. For example, I have witnessed theoretical physicists in Bhubaneshwar (in the state of Orissa in India) working jointly with colleagues at CERN essentially in real time. This has not removed the need for some face-to-face contacts and attendance at conferences, but – in theoretical subjects at least – it has facilitated enormously the performance of excellent work in diverse locations.

The cost of equipment remains a major problem, although a large number of schemes now exist that provide grants for scientists in developing countries and countries in transition, and to support collaboration with scientists in industrialised countries (some are described in the Appendix to this paper and by Gaillard, *loc cit*). The way ahead is to focus on equipping and staffing a relatively small number of national or regional centres of excellence. These centres should be based in (selected) existing universities, which could (*ab initio* or at a later stage) act as hubs for activities elsewhere. Such centres would have a much better chance of flourishing than in the past, thanks to the possibility of regular contact with peers elsewhere and the availability of much (if nothing like enough) information about new developments over the Internet.

There are of course a number of other problems. These include lack of status and inadequate salaries for scientists in developing countries, difficulties faced by young scientists (on whom many of the funding schemes are, rightly, focused) who may lack support from older colleagues, and the possibility of funding being diverted into other channels.

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[22] Intellectual property rights (ipr) generally, trade barriers, and arguments from comparative advantage, look very different from the perspective of developing and developed countries. For an authoritative discussion of ipr in relation to development, and references to work on this important subject, see the recent report of the independent Commission on Intellectual Property Rights, set up by the UK's Department for International Development – **http://www.iprcommission.org**. This report includes a discussion of copyright, and also of the protection of traditional knowledge and plants.

Collaboration is widely seen as providing a way to reduce some of these difficulties, and can also help, for example, in integrating scientists in developing countries into the international scientific community, increasing their output and visibility, and providing training. It is important, however, to recognise the potential pitfalls, which have been analysed by Gaillard (*loc cit*). Funds for collaborative projects may attract applicants in industrialised countries who have only a minor interest in working with scientists in developing countries. Cases of scientific colonialism are not unknown, in which scientists from industrialised countries have produced the proposals and published the results, while the role of their "collaborators" in developing countries has been limited to collecting data and carrying out field work. Different priorities have emerged. For example, European medical researchers have proposed working on major tropical diseases, while scientists in developing countries have given priority to preventive medicine and health problems related to the environment, such as diarrhoea and nutrition.

A Proposal: Bridge-building Fellowships

Attracting the funds to build up university-based centres of excellence in developing countries will obviously be very difficult, but attracting outstanding staff will be an even greater challenge: talent is scarcer, and more precious, than cash. The key, I believe, lies in recognising that Salam's predicament in being forced to choose between a scientific career at the cutting edge and working in – and helping – his native country, is not at all unique. I have met many young scientists who, having come to the UK from developing countries to do a PhD, or post-doctoral research, with the intention of then returning home, have faced the same cruel choice.

A solution, which would also kick-start or enhance collaborations with universities in industrialised countries, would be provided by "Bridging Fellowships" with the following features:[23]

- Fellowships would provide support for outstanding young scientists from developing countries who had just completed a PhD or a post-doctoral research Fellowship at a university in an industrialised country (UI). This support would be for (say) five years (three years in the first instance with a

[23] I am not aware of any existing Fellowships of the sort advocated here, although there are of course a large number of programmes designed to support science and technology in developing countries and countries in transition – see the Appendix to this paper for a sample.

review at the end of year two), or perhaps five plus three plus two (with continuation beyond five years dependent on obtaining a permanent position in the home country, and beyond eight on having successfully mentored a PhD student).

- The Fellows would split their time (say 50:50 for at least five years) between the university where they had done their PhD or post-doctoral research (UI) and a university in their home (developing) country (UD), where they would have the prospect of obtaining permanent positions later.

- Funds would be provided to enable the Fellows to build up a research base in their home universities, with the prospect of applying for continuing funding thereafter, assuming they became tenured.

- The Fellowships would be linked to a limited number of UDs, selected as potential centres of excellence. Ideally, a significant number of Fellowships would be created in selected/related fields at a given UD in order to provide critical mass.

- While the selected universities in developing countries and their governments would have to support the aims of the scheme,[24] it should as far as possible be driven bottom-up, ie Fellows should be awarded by international panels of experts (drawn from recipient and also industrialised countries) in response to applications, and responsibility for spending travel and research funds should rest primarily with the Fellows.

Although even a small number of Fellowships would be beneficial, such a scheme could have a really major impact with substantial funding – tens if not hundreds of millions of dollars a year (depending on how many universities, in how many countries, are involved, bearing in mind that it would probably be better to support a few centres relatively generously than spread funding thinly). Such funding is not beyond the means of some of the world's major charitable

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[24] As would the universities in industrialised countries at which the Fellows had worked, given that a major part of the idea is to lay the basis for on-going collaboration. Probably scientists from any UI should be eligible, although perhaps the UIs should also be limited in number in order to facilitate the formation of effective research networks involving the UIs and the UDs, in addition to bilateral collaborations. The African Economic Research Consortium (**www.aercafrica.org**) provides an example of a successful network, designed to "strengthen local capacity for conducting independent, rigorous inquiry into problems pertinent to the management of economies in sub-Saharan Africa".

Foundations, and I would hope that the countries involved and the World Bank would also be prepared to provide funding. The benefits would include:

- For the selected universities in developing countries (UDs), a way to recruit and retain outstanding young people and build up links and collaboration with the universities where they had done their PhDs or post-doctoral research (UIs).

- For the Fellows, the chance to carry out cutting edge research with state-of-the-art equipment while returning to their home countries.

- For the universities (UIs) at which the Fellows had done their PhDs or post-doctoral research, part-time (50 per cent) Fellowships for outstanding young researchers, and a chance to strengthen research links with universities in developing countries. These links are obviously important in fields such as agriculture and tropical diseases, and their value would grow in all fields as the centres of excellence prospered.

Detailed implementation of the proposed Bridging Fellowships would of course have to be tailored to the circumstances in the countries involved (critical questions being which universities should be involved, and what disciplines should be given highest priority). Various additions or variants might be worth considering, such as:

– (competitive) provision of travel funds/Fellowships and research funds for academics in the chosen fields already at the designated centres of excellence (UDs), in order not to create different categories of staff there.

– linking the Fellowships to networks of expatriate scientists and engineers from the countries involved, who could support the Fellows' work in various ways, along the lines of the Colombian network of researchers abroad, Red Caldas,[25] which provides support for researchers in Colombia.

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[25]Red Colombiana de investigadores en al exterior – http://atenea.ucauca.edu.co/~arendon/colombia/r-caldas.html.

– involving industry as a partner in funding some Fellowships, with provision of consultancy by the Fellows (or their former PhD supervisors) as a possible quid pro quo.

– creation of Fellowships designed to repatriate established academics, perhaps by establishing joint Chairs at UDs and UIs. This might be a priority for some countries, such as China (where there is significant support for research in the leading universities, and there is already a small reverse brain drain). However, persuading émigrés to return home becomes increasingly difficult as they become more established (with children in school etc), and in general I believe that Bridging Fellowships for post-doctoral scientists would have the biggest impact.

Conclusions

It should be stressed that there are many other successful examples and forms of international scientific collaboration besides those I have discussed (eg the dispersed collaborative research networks that operate in geophysics). My conclusions, however, are general. Namely, scientific collaboration can

– accelerate the progress of science,

– help create and strengthen bridges between diverse societies, and

– play a role in conflict mitigation, building on scientific networks and mutual professional respect.

While many of the examples I have given date from the Cold War era, I hope that collaboration at SESAME will play a role in bridge building in the Middle East, and scientific collaboration might also, for example, play a modest role in creating better relations between India and Pakistan.

There is a widespread consensus that building scientific and technological capacity is important for development, and that partnerships and collaboration can play a critical role in capacity-building.[26] The way ahead must surely be to

[26] To give a final example, the African Capacity Building Foundation (**http://www.acbf-pact.org**) , which was created in response to the "chronic shortage of human and institutional capacity in Africa", includes in its principles the "centrality of capacity to the development process" and the "critical role of a partnership approach in addressing the capacity problem".

concentrate on building up national or regional centres of excellence. I believe that the Bridge-building Fellowships proposed here could play a key role by helping to stem the brain drain, and underwriting mutually beneficial collaboration and networking with universities in industrialised countries.

If the proposed Bridge-building Fellowships survive the scrutiny of those better acquainted than I with the developing world, I hope that they will attract the interest of the governments of some developing countries, charitable Foundations, and the World Bank. In order to make a big impact, a substantial investment would be needed. But I believe that the returns would be enormous.

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Appendix: Support for Scientific Capacity Building in Developing Countries and Countries in Transition

To the best of my knowledge, nothing like the Bridge-building Fellowships proposed in this paper already exists. There are, however, a large number of programmes designed to foster science and technology in developing countries and countries in transition by different means, almost all of which recognise the importance of supporting young scientists and of partnerships and collaboration. The following is a sample (see also Gaillard, *loc cit)*, in alphabetical order:

The African Institute for Mathematical Sciences (**http://www.aimsforafrica.org**) is a new centre based in Cape Town designed to promote mathematics and science in Africa, recruit and train talented students and teachers, and build capacity for African initiatives in education, research and technology. It will initially focus on a one-year postgraduate course, for students

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The ACBF's programmes focus on economic policy analysis, financial management and related issues.

with good maths, science or engineering degrees from across Africa, which will cover many of the most exciting areas of modern science, taught by outstanding African and international lecturers.

The Centres of Excellence for Technological Innovation for Sustainability in Africa (CETISA) partnership. The Sustainable Development Programme of the Royal Institute of International Affairs has brought together over forty universities, research organisations and governments in Africa and the rest of the world to form the CETISA partnership which aims to catalyse the development of a network of centres of excellence. Workshops are being organised to develop a proposal for regional centres of excellence on fresh water and energy (which might be followed by centres on, eg, ICT, agriculture, and industrial manufacturing). Further details may be obtained from **Fanny.Calder@riia.org**.

The International Council for Science (**http://www.icsu.org**) aims, *inter alia*, to "facilitate interactions between scientists…from 'Developing' and 'Developed' countries".

The International Foundation for Science (http://www.ifs.se), which "believes that the interests of both science and development are best served by promoting and nurturing the research efforts of young science graduates, who are at the beginning of their research careers", provides "support to developing country scientists to conduct, in a developing country, relevant and high quality research on the management, use, and conservation of biological resources and the environment".

The International Network for the Availability of Scientific Publications (**http://www.inasp.info**), created by the International Council for Science in 1992, has as its mission to enhance the flow of information and knowledge within and between countries, especially those with less developed systems of publication and dissemination. It aims to promote in-country capacity building for the production, organisation, access and dissemination of scientific and scholarly information and knowledge.

The International Science Programme (**http://www.isp.uu.se**) operates programmes in Physical Sciences, Chemical Sciences, and Mathematics designed to assist "carefully selected groups and networks" in low income countries in Africa, Asia and Latin America, on a long term basis designed to allow the networks to become self-sustaining (grants of $[10-70]k pa per group or network can provide equipment, consumables, literature, exchange of scientists, postgraduate sandwich courses, conferences etc).

The Millennium Science Initiative (http://www.msi-sig.org) seeks to strengthen the science and technology capacity of developing countries through integrated programmes of research and training planned and driven by local scientists. These programmes are linked in partnership with other programmes, local governments, and the international scientific community. The MSI is currently thriving in Chile, Brazil and Mexico, and is well on its way to fruition in sub-Saharan Africa and in Vietnam.

The Third World Academy of Sciences (**http://www.ictp.trieste.it/~twas)**, which was initially led by Abdus Salam, supports a range of activities in developing countries (through research grants, Fellowships, Prizes, support for meetings etc) which are designed to "promote scientific capacity and excellence for sustainable development in the South".

The Wellcome Trust's International Biomedical Programme (**http://www.wellcome.ac.uk**) facilitates collaboration between scientists in the UK and in developing and restructuring regions by funding of exchanges that allow UK scientists to spend time in overseas laboratories and vice versa.

Finally, there are various scholarships available to support students from developing countries who wish to study for a PhD at universities in industrialised countries (although the number of such scholarships may be inadequate).

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