The Global Research Village: A View from the Periphery

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A background paper commissioned by the International Development Research Centre (IDRC).

** Views expressed are those of the author, and do not necessarily represent those of IDRC.*

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Summary

There is a vast difference between the rich and poor countries in every respect. The difference is very pronounced in scientific and technical research, in terms of both volume and impact. Indeed the distribution of science is even more skewed than the distribution of wealth among nations. Science in the developing countries suffers from poor funding, poor laboratory and library facilities, low productivity and poor visibility. Developing country scientists have access to only a tiny fraction of the information they need and their own contribution to science is hardly noticed by others. They are often the also-rans in world science and are rarely members of international invisible colleges or collaboratories. It is important that these countries strengthen their scientific research and their scientists become fully integrated members of the worldwide network of science. But, unfortunately, the transformations effected in the conduct of science with the advent of the new ICTs (such as high bandwidth Internet) and the ever-increasing cost of subscriptions to journals and secondary services are widening the gulf between the industrialized and developing countries. Ironically, the steep rise in the cost of S&T information has helped Third World scientists in a way, as it forced scientists and librarians in the advanced countries to think of measures to overcome the 'serials crisis' many of which can benefit Third World scientists. These include, among others, the Open Archives and E-print Initiatives, Public Library of Science, the Budapest Open Access Initiative, SPARC (the Scholarly Publishing and Academic Resources Coalition), and BioMed Central. Also, eminent scientists like Bruce Alberts and editors like Richard Smith and world leaders like Gro Harlem Brundtland are championing the cause of enhanced access to information for Third World scientists. In response to such moves, commercial publishers of journals have allowed free delayed electronic access to a few high impact journals through institutions such as the Highwire Press of the Stanford University. Under WHO's Health InterNetwork, more than 25 commercial publishers have agreed to provide free (or low-cost) web access to about 2,000 biomedical journals for scientists, faculty and students working in universities, hospitals and other public institutions in the poor countries. To benefit from these initiatives, scientists in the Third World should have access to PCs and high bandwidth Internet, and many of them do not. As Bruce Alberts suggests, even if it means subsidising, such access must be ensured. Agencies such as the Third World Academy of Sciences, Inter Academy Panel, and the Inter Academy Council and Foundations such as the Soros Foundation, Rockefeller Foundation, Andrew Mellon Foundation, and the Bill and Melinda Gates Foundation should work in unison to facilitate free flow of S&T information for the benefit of scientists and people everywhere. Scientists everywhere should stop publishing in expensive commercial journals and support efforts aimed at democratising access to scientific information. All this is easier said than done. Commercial publishers will not easily let go the stranglehold they enjoy now, and those who want to bring about drastic changes are dispersed around the world and cannot really act as a cohesive body that can take on the might of the commercial publishers. Mere idealism cannot win. Scientists in developing countries should take advantage of recent initiatives to open up free and low-cost access to scientific and technical information, examine the pros and cons of different possibilities that have become available and choose the right options and enlist the support of key organizations, both national and regional and international. They should become proactive.

Knowledge is the single most important commodity in driving socio-economic development in today's globalizing world, and intellectual capital is going to be as important as financial capital. Information and communication technologies (ICTs) are playing increasingly important roles in the production, transmission and utilization of knowledge. It is to understand the dynamics of ICT mediated knowledge activities and to benefit from them, OECD had established the conference series called The Global Research Village (hereinafter referred to as GRV). So far three conferences [1-4] have taken place: Denmark, 1996; Portugal, 1998; and The Netherlands, 2000. The fourth in the series will take place later this year in Poland. These conferences are usually attended by people from the developed countries, mostly Western Europe, and are concerned with science policy issues of the industrialized countries. Although some thought was given to the concerns of science and scientists in the developing world in the three conferences held so far, it has not been followed up with appropriate action. For example, the first conference held in Denmark discussed the implications of information technology in higher education in S&T in developing countries and brain drain. While it was generally agreed that sustaining the diffusion of IT in the science system of developing countries would be difficult without a general building up of human resources, there was also the perception that developed countries were less interested in 'giving' to developing countries and more interested in 'selling' to them and that there was a big gap between what developed countries profess and what they actually do in the matter of development [5]. The major theme of the second conference held in Portugal was 'how ICTs affect the science system'. A variety of topics were discussed including how ICTs are changing the way scientists communicate, access information, improve instrumentation, set up research collaboratories and publish and disseminate their findings electronically. Again the developing countries figured only marginally. The Amsterdam conference in 2000 on access to publicly financed research emphasised the need for Northern countries to give priority to building up a research culture and adequate research capacity in developing countries. But unfortunately the transfer of basic knowledge and the development of opportunities for knowledge generation in the developing countries continue to remain neglected. GRVs are not the only conferences to deal with the issues of science at the global level. There was the Millennium Science Summit at Budapest, 2000, which gave pride of place to science in the developing world, but then I doubt if the rhetoric would ever be translated into action. As pointed out by Prof. Bruce Alberts, "most of the international organizations established by the United Nations with the great hope of using science and technology to improve the human condition are seriously hampered by bureaucracy and lack of energy, innovation, and resources." The GRV conferences are far more likely to lead to concrete action, at least as far as the action can benefit the industrialized world.

The documents from the three GRV conferences, both background material and the proceedings, are of high quality and have some very useful and practical suggestions for what they call 'the global research village'. The idea of viewing the world as a village is a few decades old. It all started with the awesome power acquired by communication technologies that helped greatly in reducing the barrier of distance and enabled instant communication. Unfortunately what is referred to as global only covers the rich man's world - for convenience sake, the OECD countries - and leaves out vast areas and huge populations living in what used to be called the Third World and what is now called developing and least developed countries.

The developing countries are 'excluded' largely because of the vast differences between them and the richer countries that are covered by the 'global' initiatives – the economic, digital and other divides. It is a fact of history that modern science and technology which made the Western World what it is today did not have the same transforming effect on the rest of the world. Is it at all possible for the developing countries to get integrated into the 'Global Research Village'? Let us not have any illusions. Full integration is at best a long way off if ever it can happen. That does not mean we should abandon all hopes and refrain from doing something about it. [Remember the Americans were nowhere near the top in world science at the turn of the last century. Indeed young American students, keen on doing something significant in science used to go to the great centres of learning in England and Europe. But then by the end of the Second World War the United States of America became a formidable scientific and technological power and started attracting scientists and scholars from every part of the world.]

This brief report looks at doing research in the developing world and how can we harness the new technologies to achieve information equity. It begins with delineating the dimensions of the divide, as it affects the performance and utilization of scientific research, and goes on to describe efforts already afoot to bridge the divide, and finally lists possible courses of action. In particular, the report discusses the implications of the new ICTs for research in the developing countries: left to themselves, these technologies will only exacerbate the existing divides and make things worse. [As Rev. Jesse Jackson pointed out a few years ago, even in the technologically advanced United States of America, the relative disadvantage suffered by inner city communities - largely Blacks and Hispanics - was exacerbated with the spread of the new ICTs. As he put it, the digital divide exacerbated the racial ravine!] But the new ICTs also have the potential, if only we know how to use them, to bridge the divide and integrate science done everywhere. They can, as hoped by Bruce Alberts, empower each individual scientist - for the first time - with the means to close the gap between the knowledge resources available in industrialized and developing nations.

The centre – periphery dichotomy in world science

Ideally speaking, science is a truly global endeavour that knows no frontiers. Together with technology, science has long been recognised as an essential driving force in the development process. In principle, anyone anywhere can contribute to the growth of knowledge in the sciences and take advantage and make use of the collective knowledge, provided one has the inclination and capacity to do so. Also, scientific findings, be they concerned with the Sun and the stars, the earth, the human body, the plant, animal and mineral wealth on our globe, or abstract phenomena such as mathematical equations, are universally valid, irrespective of whoever discovers them. The cognitive content of science, with rare exceptions, is context free. To that extent science is universal. *But in reality there are limitations to the universality of science – largely a result of the differences in the social, intellectual, and economic structures of the different civilizations.*

In the real world, production and efficient utilization of scientific knowledge are highly concentrated in a few countries. A large majority of countries – those on the periphery - contribute precious little to the world's growing pool of scientific knowledge. What is more, the gap between the developed and the developing countries is widening, with a few exceptions. There were 3,800 scientists and engineers per million of population in the USA as of 1990, as against less than 200 per million in the South. For the years 1994-96, there was an average of 300 scientists and engineers (full time equivalent) per million of population in the South, as against the industrialised country average of 3,300 [6]. These are mere numbers, not taking into account the quality of the training and the resources at the disposal of the scientists. A single company such as General Motors, it is said, invests far more on research than the entire R&D budget of India, a leading performer of science in the developing world. As in development economics, in science and technology also, the periphery is very much dependent on the centre. Peripheral countries, with a few exceptions, perform little research and depend on imported books and journals and now electronic sources of knowledge. Education in these countries, at least in science and technology, is largely based on foreign knowledge and much of the technology is imported.

In essence, science on the periphery is characterised by

(i) poor funding, much of it coming from the government [For example, India invests less than 1% of its rather low GNP on research, compared to 3.6% of GNP in Sweden. While in OECD countries, about 30% of R&D is publicly funded and the rest largely funded by the private sector, in developing countries, the bulk of the funds for research, often more than three-fourths, comes from the government.]

(ii) the absence of a viable scientific community [Often, there will not be a critical mass of scientists in a given field in the country], and negligible level of membership in international invisible colleges,

(iii) an insularity resulting from inadequate access to relevant information and inadequate communication within the local scientific community and with international invisible colleges [The volume of intellectual exchange with other scientists through face-to-face meetings, conference participation and correspondence is often negligibly small. In particular, very few developing country scientists attend and speak at important international conferences],

(iv) an unduly long time lag before participants in peripheral societies can take part in hot/ emerging research fronts [Rarely do developing country scientists work in emerging research fronts; by the time they are ready to work in one of these areas, the world's attention would have moved to other newer areas],

(v) as pointed out by P V Indiresan, former director of Indian Institute of Technology, Chennai, science and technology in developing countries often lack originality

[As a senior technocrat ruefully admitted recently, Indian technology is always a little late, never up to date. At its best, Indian technology is good enough to be an import substitute but not good enough to be a force in international trade. Speaking about Indian technology, Indiresan says, "never in our long history have we initiated any major technological breakthrough. We have nothing to compare with the Chinese boast of the invention of writing paper and gunpowder. Truly speaking, Indian technology was never good enough to confront international competition. That is why every time foreigners invaded us, we lost - our technology was not good enough." This is true of all countries that were colonised.]

(vi) weak institutional infrastructures [Scientific and scholarly academies and research journals in developing countries are often poor imitations of those in advanced countries; they may exist merely in form lacking in substance and content. More importantly, peer review system is rather weak, and scientists are afraid to criticize one another's work. In the early 1970s, when I joined the staff of a premier Academy of Science, I pointed out, to the great annoyance of senior Fellows of the Academy, that there were many Fellows who were in but ought not to have been elected in the first place and there were many who were out but ought to have been elected long ago. Fortunately, the Council of the Academy accepted the suggestion in the right spirit and enlarged the number of Fellows that could be elected in a year to 100 for two years and brought in about 170 new Fellows in those two years, instead of a maximum of twenty according to the statutes.]

(vii) an excessive dependence on science done in the centre, the source from which influence radiates, for its growth and sustenance, and

(viii) negligible contribution to the world's pool of knowledge, much of which may not be relevant to their immediate needs.

Science, at best, is a marginal activity in most developing countries. Research effort is generally insufficient in most developing countries to have any real impact, and remains confined to a few sectors and a few disciplines. Points out the *Second European Report on S&T Indicators*, "The two main weaknesses exhibited by these countries – a lag in economic and social sciences, and weakness in engineering – make them continuously dependent on external assistance." More importantly, it is rarely, if ever, that scientists on the periphery take part in the collective endeavour of setting the research agenda in any discipline or research front. No wonder that the centre views the periphery as a source merely of data gathering and survey-related research and not as a partner in the tasks of theoretical synthesis and proposing new theoretical configurations [7].

Not all developing countries are on the same boat. Some like India and China have a large and reasonably developed S&T base that is capable of sustaining programmes on developing missiles, nuclear bombs and space satellites. Many ASEAN countries have a good science base too. Nevertheless, on the whole, a very high proportion of populations in developing countries are still not reached by the benefits of modernity and suffer from persistent social, environmental and health problems.

Some Indicators

Let us look at some literature-based evidence to realise the dimensions of the centre-periphery dichotomy in science. As seen from the CD-ROM version of *Science Citation Index* 1998, only fourteen countries had published more than 10,000 papers in the year (Table 1). The United States of America continues to remain the world's leading performer of science (with close to 200,000 papers indexed in *SCI* 1998), followed by other G7 countries, viz. Japan, the United Kingdom, Germany, France, Canada, and Italy, and Spain, the Netherlands and Sweden. If in the ancient times much of the knowledge about the natural world came from India and the Arab world, in modern times science is dominated by the Western world. Only two developing countries, People's Republic of China (13,878 papers) and India (11,437 papers) figure in this list. In the Middle East, Israel is the only country performing substantial volume of scientific research (more than 7,500 papers in *SCI* 1998). The only three other non-Western countries that published more than 5,000 papers, indexed in *SCI* 1998, are South Korea, Taiwan and Brazil. Even within developing countries (and regions), there is a tremendous disparity in the distribution of science. The scientific output of some of the leading developing countries is less than that of a single university department in scientifically advanced countries. Malaysia, Philippines, Thailand, Indonesia, Pakistan, Sri Lanka, Bangladesh, Venezuela, Peru, Cuba, and virtually every country in Africa (except South Africa) had published less than 1,000 papers – in many cases less than 500 - each in 1998. If we look at the number of papers published per unit population, the gap between the developed and the developing countries will become even more dramatically evident.

In Table 2 we give the number of papers from five selected countries indexed in *SCI* over twenty years. Except India, every other country has recorded good growth, and in particular the growth in both China and South Korea is spectacular. Brazil and Israel have also done well.

As John Davidson Frame pointed out in 1977, the distribution of mainstream science production is even more skewed than the distribution of wealth among nations, with over 80% of the world's mainstream scientific literature being produced by the top ten countries [8]. In spite of the rapid strides made by countries like China and South Korea, the situation has not changed much in the past quarter century. A recent study by Anna Maria Cetto has quantified the unequal distribution of scientific activity and scientific journals not only between the industrialised and developing countries but also within developing countries [9]. Of the more than 140,000 titles listed in *Ulrich's Directory of Scientific Serials*, close to 80% are published in North America and Europe. In contrast, all the developing countries taken together, with 80% of the world's population, produce 13% of the titles. Again, mere numbers and percentage shares do not tell the full story. Most journals from developing countries suffer from limited circulation and lack of visibility. The world over, both librarians and end users prefer to subscribe to, and read, journals produced in North America and Europe and ignore developing country journals. Most of the current awareness and abstracting services, as well as numeric and factual databases, are compiled and produced in the advanced countries and they index only a few developing country journals.

Many people have reservations in using *SCI* data for measuring the volume of scientific research performed in different countries. While it is the only major international multi-disciplinary science and technology database that indexes papers from significant journals in a wide variety of fields and while till recently it was the only database to provide citation information, its coverage of journals has been questioned. Among the weaknesses pointed out are its English language bias and poor coverage of developing country journals [10]. For example, *SCI* indexes about a dozen journals from India although India publishes more than a thousand journals in science and technology. [At one time or the other *SCI* has indexed more than forty Indian journals, but most of them could not meet the standards set by the publishers of *SCI* and were dropped]. One can look at the numbers of papers indexed in several other subject-specific international databases, such as *Mathsci* (published by the American Mathematical Society), *PubMed* (produced by the National Institutes of Health, USA), and *Chemical Abstracts* (published by the American Chemical Society). We give in Table 3 data for just India and China, the two leading performers of science in the developing world, and which are middle-level countries in science with their own space and nuclear energy programmes [11].

We see that China publishes about 10 percent of the world's papers in both chemistry and mathematics (including statistics and operations research). This is of course a recent phenomenon. About ten years ago, China performed very much less science. Indeed China and South Korea are the two countries catching up fast with the advanced countries. India remains virtually at the same level.

The low volume of medical research carried out in both China and India is striking. It leads to the question whether developing countries do research relevant to their needs. Probably not. India accounts for more than 23 percent of the world's incidence of tuberculosis and China 17 percent and yet their share of world research is very low [11]. India and China together account for over 26 percent of prevalence of diabetes in the world and yet together they account for less than 2 percent of world's research in this area [12]. As far back as 1990, there were 2.3 million deaths in India due to cardiovascular diseases and 2.6 million deaths in China. And yet these countries together account for less than 2 percent of world's research in cardiovascular diseases [13].

We compare the contributions of India and China to the world literature of tuberculosis and percent share of incidence of tuberculosis in these countries with those of some selected advanced countries in Table 4. The tremendous gap between what is needed and what is actually done by way of research in the developing countries is driven home dramatically by these figures. The ratio % world share in research / % world share of disease burden is even lower for India and China in the case of diabetes [12].

There is another kind of relevance – relevance to emerging frontlines of research. In their research papers, most developing country researchers tend to quote relatively old references. A cursory glance of *Journal Citation Reports* reveals that almost all developing country journals quote a much higher percent of older references and a much lower percent of recent references than mainstream journals in the same subject areas. In other words, most research reported in these journals are not of much current relevance.

It is not just the volume of research done in developing countries and the relevance of the research to the immediate needs of these countries which are low but its impact and influence on science per se and its applications are also low. One hardly ever sees papers from developing countries in influential journals such as *Nature*, *Science, Proceedings of the National Academy of Sciences, USA*, and *Cell*. As pointed out by Prof. C N R Rao, President of the Third World Academy of Sciences, many university departments in the Western world publish larger number of papers than all the laboratories in India put together in leading journals of the world such as the *Journal of the American Chemical Society*. Most papers from developing countries are published in low-impact journals and journals not indexed in important international secondary services. They are, with some exceptions, hardly ever read or referred to by other researchers. In other words, much of science done in these countries lacks visibility.

Scientists in developing countries, figuratively speaking, often live in islands of their own. Looking at citations to their papers, one finds that only a very small fraction of the citations comes from advanced country researchers and high impact journals, whereas developing country scientists quote a very large number of papers of advanced country scientists. Which is to say that while they draw upon the rest of the world's knowledge for their survival as scientists, their own contributions make hardly any dent on science performed elsewhere. What is more, whatever little is quoted of their work is quoted within the same disciplines. Unlike in science at the cutting edge, there is very little interdisciplinarity in developing country science.

Comparing science in the developing countries with that in advanced countries, one is reminded of Ilie Nastase's brief but telling comment on his contemporary Bjon Borg's absolute mastery in tennis in the 1970s: "They should send Borg to another planet. We play tennis; he plays something else." Only the difference between mainstream science and science on the periphery is even more pronounced, so much so the late Michael Moravcsik had compared the scientists in developing countries to a bird whose wings have been clipped but nevertheless tries to fly.

One characteristic feature of science today is the rising levels of international collaboration. One simple measure of such collaboration is the number of papers jointly authored by researchers from different countries. According to CNRS-LEPI, internationally co-authored papers as a percentage of a country's total publications rose for virtually all OECD countries between 1976 and 1986 [14]. For example, Switzerland's share of internationally co-authored papers rose from 20.7 percent in 1976 to 32.3 percent in 1986. According to the *European Report on Science and Technology Indicators*

(1997), between 1985 and 1995, internationally co-authored publications, as a percentage of all the publications from a country, rose dramatically in most European countries [15]. For instance, from 31.8 percent in 1985 the percentage of internationally co-authored papers in Switzerland rose to 47.3 percent in 1995. Corresponding figures for Italy were 20 percent in 1985 and 33 percent in 1995. In the UK, international collaboration, which grew at a yearly growth rate of 0.86 percent, was the fastest growing component of collaborative research [16]. According to *Science and Engineering Indicators 1998* of the US National Science Foundation, the number of internationally co-authored papers worldwide increased by 200 percent between 1981 and 1995 – from 21,000 or 6 percent of papers to 63,800 or 15 percent of all papers [17]. During the same period, the total number of papers published annually increased by only one-fifth. Much of this collaboration takes place among the OECD countries, especially the G7 countries. For example, both in 1981 and in 1986, OECD countries accounted for more than 81 percent of internationally co-authored papers [14].

In Table 5 we present recent data on the numbers of papers resulting from collaboration among the rich (G7 and European Union) countries [18] and in Table 6 the numbers of papers resulting from international collaboration involving selected developing countries from Asia, Latin America and South Africa [18]. Most of the numbers in Table 5 are either four-digit or three-digit numbers, whereas except for four three-digit numbers all other numbers in Table 6 are either two-digit or single-digit numbers. Of these four two involve Japan, an OECD country. As seen from Table 7, very few papers result from international collaboration involving African and Latin American countries [18]. This is not surprising as developing countries perform very little science. What is more significant is that the percent share of internationally co-authored papers of developing countries is very much smaller than that of the developed countries. Thus not only is science dominated by a few advanced countries but scientific collaboration is dominated by them as well.

Why science in the developing countries?

Why should we be concerned about this tremendously skewed distribution of scientific research among nations (and regions)? There is one good reason. *The production of new knowledge will be hampered if research is restricted to certain parts of the world and if only a selected few take part in the activity.* Take for instance India. If India had opened the doors to higher education to a much larger population at the turn of the 20th century than it did there would have been many more Indian scientists of world class today. Indeed, many leading Indian scientists today are first generation graduates whose parents have not had the advantage of higher education, and in many cases any education at all. Ganapathy Baskaran of the Institute of Mathematical Sciences, Chennai, is an outstanding example of such first generation achievers. After winning a Masters in Physics with a gold medal from American College, Madurai (Madurai Kamaraj University), where he had the good fortune of having an American missionary as his teacher, he went to the Indian Institute of Science, Bangalore, for his doctoral work. Initially he was refused admission to the Ph D programme in physics, as he had not scored a first class in his pre-university examination. [For many first generation college-goers in southern India, the pre-university class is a bit tricky. It is in this class that they start learning and writing examinations in English, unlike in school where they learn everything through their mother tongue. Unlike richer kids who attend English medium schools, most first generation collegians find this transition a bit difficult.] Baskaran was determined to do physics. After a few months as a student of applied mathematics, he met the director of the Institute and told him that he did not really enjoy what he was doing. If the Institute was giving him a scholarship why would it not let him do what he would really enjoy? The director, one of the finest managers of science India ever had, saw the point and overruled the objections of the Physics Department and allowed Baskaran to register for Ph D in condensed matter physics. Today Baskaran is one of the most respected alumni of the Institute, a world class condensed matter theorist, invited often to work in places like Princeton University and the Institute of Advanced Study, Princeton, NJ. His work is well cited and his students are welcome in the best of universities. Another well-known example is A P J Abdul Kalam, the new President of India and the man who till a few years ago led the Indian defence research; he was the first graduate in his family; neither his parents nor his siblings have been to college. But Baskaran and Kalam are exceptions. As pointed out by astrophysicist Subrahmanyan Chandrasekhar, not many developing country scientists exhibit such high degree of motivation and character.

As science is a collective enterprise, the greater the number of people doing research the better it will be for the production of new knowledge.

Unfortunately, because of the way institutions are run and the way admissions to higher education and research are made, in many developing countries we find a large proportion of scientists being mediocre and some of them holding key positions. *That is why there is a great need for strong institutions*. Bruce Alberts said, in his 2002 presidential address to the National Academy of Sciences, “Most of us take successful institutions for granted, and we vastly underestimate their value. I have met many talented scientists who live in nations that lack strong institutions for science. These scientists are very frustrated, because they feel unable to make the contributions they should to their own society.” [19] He believes that every nation must have involved and effective institutions, run by the nation's own scientists and engineers and he wants the scientists of the world to exploit fully the new communication technologies to share information and other resources that strengthen world science. Countries at different stages of development will need different types of scientific and technical expertise, and would be expected to provide different levels of investment in science. Even the poorest nations must have scientists who are deeply involved in education at all levels, so as to produce the human capital on which so much of development depends. And these nations must also have enough talented individuals and effective institutions in areas such as agriculture, environment, and health to allow them to choose wisely from the increasingly vast store of the world's scientific and technical knowledge to meet local needs. Any country without such a core of scientists and technologists can expect to be completely cut off from the invaluable knowledge and know how of the world's scientific community. The NAS report *Our Common Journey* emphasises the need for vigorously harnessing new scientific and engineering talents - such as the first generation science graduates referred to earlier. "If we are to make long-term progress on our goal of producing a safer, more just world for our grandchildren, scientific capacity building and cooperative research programs deserve to be at the centre of each of our international assistance programs," says Alberts.

There is a second reason for developing countries to take part in the worldwide enterprise of scientific research. As the 10/90 report of the Global Forum for Health Research states, it is necessary for developing countries to develop the research capacity necessary to deal with their own health problems through evidence-based decision-making [20]. Less than 10% of the worldwide expenditure on health research and development is devoted to the major health problems of 90% of the population. Wealthy nations pursue drugs to treat baldness and obesity, depression in dogs, and erectile dysfunction. Elsewhere millions are sick or dying from preventable or treatable infectious and parasitic diseases. There is a fundamental mismatch, expressed as millions of lives lost each year, between human needs and scientific innovation. If India and China are the leading sufferers of tuberculosis and diabetes in the world, it is in their own interest that they do part of the research to combat these diseases. Take tuberculosis. By the early 1990s, while TB was responsible for 2.8% of the entire burden of ill health in the world, research on TB, at about US $33 million in 1993, accounted for less than 0.1% of the world's expenditure on health research and development. Funding for health research expressed as expenditure per DALY (disability adjusted life years) is ridiculously low for TB, viz. $0.68 per DALY in 1990) compared to asthma ($13.22), and blindness ($10.09). Second, TB in India and China is different from TB in the advanced countries of the West. While most TB isolates from the West have ten or more copies of IS 6110 and H37Rv and the sequenced isolate has 16 copies, a significant proportion of TB isolates from India have 0, 1 or 2 copies of IS 6110. The need for developing new drugs against *Mycobacterium tuberculosis*, in view of the ever-growing emergence of new strains resistant to currently available drugs, and the limited efficiency of BCG vaccine against TB in adults and non-pulmonary forms of TB in India are additional reasons why India should pursue research in TB vigorously [11]. In the case of diabetes also, as Andrew Hattersley, the eminent British diabetologist, points out, what works in the UK may not work in India and vice versa, as environmental and genetic factors can make a difference [21].

Jawaharlal Nehru, free India's first Prime Minister firmly believed that even poor countries should do science. "It is science alone that can solve the problem of hunger and poverty, of insanitation and illiteracy, of superstition and deadening customs and traditions, of vast resources running to waste, of a rich country inhabited by starving people. Who indeed can afford to ignore science today? At every turn we have to seek its aid. The future belongs to science and to those who make friends with science." It was through research on high-yielding varieties of wheat and rice that Monkombu Swaminathan, along with his colleagues in the Indian agricultural research establishment, saved India in the 1960s from recurring famine and transformed India from a regular food importing country into a food surplus country.

There is one more reason for developing countries to have a robust and viable research enterprise. Many ancient societies, such as India, China, the Middle East and Amazonia had well-developed scientific traditions, elaborate and firmly established theories of life and well-established traditions of education long before the Western World. But ever since modern science came on the scene in 17th century Europe, with its basis rooted in rationality and the conception that nature is measurable and therefore potentially controllable, it turned out to be an unprecedented intellectual revolution and a powerful engine of growth and progress. It virtually eclipsed pre-Western scientific traditions and knowledge systems. This is nowhere so amply evident as in ethnobotany and plant-based medicine. Today multinational pharmaceutical companies send out scouts to Amazonia, the jungles of Africa and the Western Ghats in India in search of for plants that have been used in traditional pharmacopoeia and to learn about their use from indigenous medical practitioners – the shamans of Columbia and Costa Rica and the Ayurvedic acharyas and Hakims of India. They take back tonnage quantities of these plants – roots, barks, nuts and whatever else is useful – and convert them into powerful drugs using the methods of modern science – computer heuristics, combinatorial chemistry, rational drug design based on pharmacophore model generation, computer-aided compound selection and state of the art analytical tools. Not only are the advanced countries – the centre - strong in modern mainstream science and technology, which had its origin in Europe a few centuries ago, but are also doing well in and deriving greater benefit than the periphery from non-Western systems of knowledge. An example of the operation of the Mathew effect – the better-endowed cornering a greater share. *If the bioresources-rich traditional societies are to take full advantage of their natural wealth, and not lose the advantage of having those natural resources, they ought to strengthen their research capacity.*

Then there are instances of clever individuals and institutions in the West trying to apply for patents on the use of certain natural products, which are well known for centuries in certain traditional societies. A classic example is a patent accepted by the US patent office on the wound healing properties of turmeric. Indian women have been using turmeric for this and other purposes for centuries. It is after a protracted litigation that the Indian government could force the withdrawal of the patent. Luckily the Indian team could lay their hands on some ancient documents and satisfy the conditions of documentary evidence of prior art. A strong science base can be the best defence in such situations.

Information key to science development

We have seen that developing countries perform very little research and that their participation in international collaboration is much less than that of advanced countries. Now we shall look at the role of information and communication in research and how research in developing countries suffer for want of access to information.

Research or production of knowledge is at once an intensely personal and a social activity. In one's quest for exploring unknown territories one would often feel the loneliness of a long-distance runner – that is the personal aspect. Research is essentially a cerebral activity. But one also needs tremendous experimental skills to succeed. The aggregation and advancement of knowledge takes place by collective efforts of researchers around the world. In the production of new knowledge scientists use what is already known. As Newton put it, if we see further it is because we stand upon the shoulders of giants. Not only scientists are bright individuals, but they draw upon the literature (or knowledge generated by others across space and time). That is why we need huge, and expensive, libraries. Generation of knowledge is only one part of the research process; for knowledge to be useful, it should be shared with other researchers and communicated, in a suitable format, to the different users/ stakeholders. Every scientist also would like his/ her work to be used by others. In fact, every scientist dreams of his/ her papers becoming citation classics. Thus information and communication are two very important aspects of research. Scientists in developing countries are terribly handicapped in both these aspects.

Even when both information and communication were entirely mediated by the printed word, there was a big gap between the richer and poorer countries that increased with the passage of time. Let us take the example of India. In the 1920s, 30s and 40s, India did rather well in science. It was then that men of the calibre of Srinivasa Ramanujan ('the man who knew infinity', as the award-winning book by Robert Kanigel referred to him), C V Raman (India's first Nobelist in science), Meghanad Saha (known for the ionization equation named after him), and Jagdish Chandra Bose (who many believe was ahead of Marconi in recognising the existence of radio waves) performed their world class work. In those days, there were very few journals. But the journals, most of them published in the West, took a few months to arrive in India by sea, and to that extent Indian scientists were behind their Western counterparts in the matter of access to information. In the 1960s and 70s, there were a large number of research journals, numbering in the range of 50,000, and many libraries in India could subscribe at best only to a few hundreds. And although airmail delivery was possible, hardly a few journals came by air, as most libraries could not afford airmail delivery. Some enterprising publishers and vendors offered 'air-speeded delivery' which somewhat brought down the time of transit at a relatively low cost to the subscribing institution. For some reason, interlibrary lending did never pick up in India (and most other parts of the developing world). In contrast, in countries like the UK and the USA, where the library facilities are far superior and scientists would not suffer unduly if they do not have access to material from other institutions, hundreds of thousands of inter lending transactions take place every year. The net result was that scientists in developing countries suffered a great deal of relative disadvantage compared to their western counterparts.

Today many institutions in developing countries cannot afford to maintain good libraries. Most libraries in sub-Saharan Africa have not subscribed to any journal for years. If scientists in many African universities often have to rely on what they are told by newspapers, by friends or Time magazine, how can they ever compete with scientists in USA and Western Europe when there is such a vast difference in their ability to access information, either through print media or electronically, asks Seun Ogunseitan, the Nigerian journalist-turned-information provider. Indian Institute of Science, Bangalore, the best-funded library among all Indian institutions of higher education, has an annual library budget of approximately Rs 90 million (about $1.8 million). Only a handful of Indian libraries have a budget of around Rs 10 million (about $200 thousand). Peanuts compared to the acquisition budgets of even moderate university libraries in the United States. Even in the West, universities and research institutions are facing a major 'serials crisis'. The cost of journals is escalating at a rate much higher than the general inflation rate. According to the Association of Research Libraries, the median subscription cost of a journal rose from $87 in 1986 to $267 in 1999 at an alarming 9% annual growth rate. In 1986, research libraries in North America purchased on average 16,312 serial titles and 32,679 monographic titles. By 1999, research libraries purchased 15,259 serial titles, or 1,053 fewer, and 24,294 monographic titles, or 8,385 fewer [22]. No wonder institutions in developing countries are unable to subscribe to even a small number of core journals. A large part of price escalation comes from commercial publishers of S&T journals. The last few years have witnessed the emergence of many initiatives to meet the 'serials crisis' and some of them are eminently advantageous to scientists and scholars in the developing world. We will look at them in a moment.

If escalating costs of print journals has made life miserable for scientists in developing countries in particular, and scholars in social sciences and humanities, the advent of electronic sources of information has made the situation even worse. It is in the nature of any new technology to exacerbate the existing divide between the rich and the poor. The newer and more potent the technology the greater its ability to increase the inequalities. The rapid changes that are taking place in the ways new information is published, stored, disseminated and retrieved using the rapidly advancing information and communication technologies have exacerbated the relative deprivation suffered by researchers in the developing world. The new ICTs have not just made each operation faster, but have brought about a greater synergy between these operations in ways unthinkable in the earlier era mediated by print on paper.

Let me give an example. If your library subscribes to *The Web of Knowledge* as well as electronic versions of journals published by several leading publishers (such as Reed Elsevier, Academic Press, Wiley InterScience and Wolters Kluwer) with whom ISI has an agreement, you can, sitting in front of your terminal, seamlessly move from one paper in a journal published by Elsevier to the full text of another paper (which is cited in the first paper) in a journal published by another publisher. All within a few seconds with a few keystrokes or mouse clicks. Even if your library does not subscribe to the Web of Knowledge, one can move from one paper to another through CrossRef, a not-for-profit network founded on publisher collaboration. To move from one paper to the other, if you were unfortunate enough to work in a developing country, you will have to note down the reference, leave the first journal, move into the racks and search for the specific volume of the second journal and open the right page. Often the second journal may not be subscribed, in which case, you either look up an abstracting service, if it is available in your library, and be satisfied with an abstract, or ask for a reprint from the author, if you can find his/ her address. He or she may normally reply giving you a URL where you may have to pay for viewing the article. Usually this process may take several days to a few weeks and psychologists tell that one loses interest if one does not get what one wants within a reasonable time. The relative disadvantage suffered by developing country scientists in the 1920s, 30s and 40s is nothing compared to the frustrating situation of 2002.

When many journals started publishing electronic versions they started accepting manuscripts electronically and got the papers reviewed electronically. Many developing country scientists, who did not have access to personal computers, email and Internet, could neither submit their papers to these journals nor read them or act as referees. They became ‘excluded’. The irony is one does not receive papers for refereeing from a journal editor not because he is not considered good enough to referee manuscripts but because he is not connected by the right technology!

Let me give one more example to illustrate how lack of access to the right kind of technology can jeopardise one’s chances for participation in research programmes. The decline of global political blocks, expansion of convenient and not-so-expensive air travel and above all the advent of the Internet have facilitated scientific communication, contact, and collaboration. More R&D collaborations are likely to develop with Internet-facilitated innovations such as virtual research laboratories and the simultaneous use of distributed virtual data banks by researchers around the globe, and ‘grids’, which depend in a fundamental way on access to high bandwidth networks. In the West such networks have become both affordable and highly reliable. Most researchers in developing countries, even those who are eminently qualified to take part in such collaboration, are excluded simply because they do not have access to the right technology.

Thus the new ICTs, left to their own devices, will surely widen the knowledge divide or the disparities in people's capacities to do science and technology and their ability to use them to their advantage. Thanks to men like Gandhi, Martin Luther King, Nelson Mandela and Desmond Tutu, we have abolished skin-colour-based apartheid, but are letting the new ICTs to create information-access-based apartheid.

Inadequate access to literature or information is not the only problem faced by developing country scientists. An equally important problem is that research carried out in developing countries lacks visibility. Nobody notices it. Nobody quotes it. Virtually it gets buried in an obscure corner of the world output of literature. The same is true for most journals published in developing countries. Very few papers published from developing countries become citation classics or find a place in the list of key papers in an emerging research front. Toni Morrison, the first Black woman to win a Noble

Prize for Literature, once said that writing about the life and sensibilities of the Blacks did not count. It was not considered important. It was peripheral. It is the same with doing science in developing countries. After years of doing research under rather difficult conditions, one still finds oneself in the category of also-rans.

Clearly, the advent and rapid development of the new information and communication technologies have not really helped scientific research in the developing countries. The Internet access gap between the rich and the poor areas of the world is not only large, but is also growing, says the *Science and Engineering Indicators 2002*. In 1997, Internet host penetration rates in North America were 267 times greater than rates in Africa [17]; by October 2000, the gap had grown to a multiple of 540. History has shown us that any technology will exacerbate the existing divides. And ICTs have exacerbated the existing inequalities in the world of science in such a short time. But, in my opinion, one does not have to lose hope. As demonstrated by the award-winning Information Village project of the M S Swaminathan Research Foundation in India, if intelligently and innovatively used the very same information and communication technologies can become an ally in our efforts in bridging the divides. Even in the world of science and research. Let us see how.

Efforts afoot

The past few years have witnessed several developments that could make access to information for scientists in the developing world a lot more affordable. These include initiatives promoted by scientists, libraries, publishers, academies and societies. A few of them are described here.

Public Library of Science

<http://www.publiclibraryofscience.org>

The Public Library of Science, a grassroots initiative by scientists, is a non-profit organization of scientists committed to making the world's scientific and medical literature freely accessible to scientists and to the public around the world, for the benefit of scientific progress, education and the public good.

The aim is to establish international online public libraries of science that will archive and distribute the complete contents of published scientific articles, and foster the development of new ways to search, interlink and integrate the information that is currently partitioned into millions of separate reports and segregated into thousands of different journals, each with its own restrictions on access.

As a step toward these goals, scientists around the world have been circulating an open letter urging publishers to allow the research reports that have appeared in their journals to be distributed freely by independent, online public libraries of science. The response from the international scientific community to this initiative has been remarkable, and overwhelmingly positive. The open letter has been signed by more than **30,000 people** from **177** countries, as of 15 June 2002. This initiative has prompted some significant and welcome steps by many scientific publishers towards freer access to published research, but in general these steps have fallen short of expectations of the proponents of this idea.

Scientists everywhere, and especially in developing countries, should make every effort to publish their work in, and give their full support to, those journals that have adopted the policy proposed in the open letter.

To bring about such a major change in the publication of scientific research, it would be necessary for scientists to do the publishing themselves. To enable scientists to publish reports of their research so that they are made universally accessible and freely useable from the moment of publication, The Public Library of Science will launch online journals that will publish original research papers, timely reviews, essays and commentary online.

Unrestricted rights to access, distribution and use of all articles published by PLoS will be assigned to the public domain, subject solely to the condition that the original authors of each work be properly credited in any complete or partial copy or derivative work.

The journals will have rigorous peer review and high editorial standards. The journals, it is hoped, will earn the highest standing in their fields by their integrity, quality, scope, and broad distribution. The costs of peer review, editorial oversight and publication will be recovered primarily by charges to authors, which is expect to be approximately $300 per published article. Costs will be subsidized for authors from developing countries who cannot afford these charges.

All the financial records and business proceedings of the PLoS will be publicly disclosed at the PLoS Website, so that scientists, other publishers, and the public can learn from our experiment as it progresses.

Funds are being raised (from charitable organizations and other sources) to cover start-up costs and working capital for the first years of operation. Several scientists and a private charitable foundation have already made donations in support of the PLoS journals initiative. An international editorial board composed of intellectual leaders in biology, medicine and allied fields is being formed. The publishing operations are expected to commence in early 2003. For more information, one may write to <journal@publiclibraryofscience.org>.

International Scholarly Communications Alliance

<http://www.curl.ac.uk/about/isca.html>

A new international scholarly communications alliance formed by eight of the world's principal research library organizations in February 2002 will broaden access to research and facilitate transformation of knowledge dissemination. ISCA members - about 600 research libraries worldwide - are working together to support equitable access to scholarly literature and to take united action to create appropriate policies. The alliance will concentrate on ways to ensure open and affordable access to scholarship across national boundaries. Its essential partnership will be with the scholar-author, the key provider of the world's research.

An initiative of research library associations in Australia, Canada, Europe, Japan, Hong Kong SAR, New Zealand, the United Kingdom and the United States, ISCA is an action-oriented global network that will collaborate with scholars and publishers to establish equitable access to scholarly and research publications.

ISCA will engage in a series of activities that focus the scholarly publishing process on the primary goals of the academic research community, advancing the discovery of new knowledge and facilitating its dissemination. Through sharing expertise on scholarly communications issues, these organizations, whose total library budgets equal over US$5 billion and which serve well over 11 million students and faculty, will be prepared to act as a unified body in creating policies and taking actions that advance these goals. *Larger libraries in developing countries will do well to coordinate their policies with ISCA.*

As a body, ISCA will promote solutions which its members agree are necessary, practical and viable approaches. Members will then collaborate to develop, expand, and leverage initiatives to transform the scholarly communications process, including strategic and advocacy programs including but not limited to:

- SPARC [Scholarly Publishing and Academic Resources Coalition, http://www.sparc.org], the ARL-initiated effort to facilitate competition in scientific communication through the creation of high-quality low-cost alternatives to expensive commercial titles, and SPARC Europe, recently launched to provide a European operational arm for SPARC activities.
- The establishment of institutional and discipline-based archives that allow public access to content and employ the Open Archives Metadata Harvesting Protocol.

Initial members of ISCA include: the Association of Japanese National University Libraries (ANUL); the Association of Research Libraries (ARL); the Canadian Association of Research Libraries/Association des bibliothèques de recherche du Canada (CARL/ABRC); the Consortium of University Research Libraries, U.K. (CURL); the Council of Australian University Librarians (CAUL); the Council of New Zealand Librarians (CONZUL); the Ligue des Bibliothèques Européennes de Recherche (LIBER), and the Joint University Librarians Advisory Committee, Hong

Kong SAR, China (JULAC).

SPARC

SPARC emerged from the widespread perception that in scientific comunication the researchers and the laboratories - where scientific communication originates – have been forgotten or sidelined and the profit motive of commercial publishers had taken over. SPARC's avowed aim is to restore the researcher in research publishing. SPARC persuades editors and editorial board members of unduly expensive commercial journals to come out and start new journals of high qulaity. SPARC journals have become popular within a few years of their first publication. For example, the ACS journal *Organic Letters* has already registered a higher impact factor than its main commercial rival *Tetrahedron Letters*, the rather expensivs letters journal for organic chemists, founded by Pergamon Press and now owned by the Elsevier group. *Theory and Practice of Logic Programming*, published by Cambridge University Press, came into being as the entire 50-member editorial board of *Journal of Logic Programming* resigned in protest against the unreasonable rise in cost of the journal and launched the new journal. The new journal is doing much better than its costlier rival. Another SPARC partner journal, *Evolutionary Ecology Research* was founded by the former editor and editorial board members of *Evolutionary Ecology* the price of which was increasing at the rate of 19% per year over a twelve-year period. The new journal costs much less for the subscriber and is doing much better than its commercial rival.

Developing country scientists should submit their work to SPARC journals rather than to the expensive journals they are trying to replace.

Open Archives Initiative (OAI)

<http://www.openarchives.org>

The Open Archives Initiative develops and promotes interoperability standards that aim to facilitate the efficient dissemination of content. The Open Archives Initiative has its roots in an effort to enhance access to e-print archives as a means of increasing the availability of scholarly communication. Continued support of this work remains a cornerstone of the Open Archives program. The fundamental technological framework and standards that are developing to support this work are, however, independent of the both the type of content offered and the economic mechanisms surrounding that content, and promise to have much broader relevance in opening up access to a range of digital materials. As a result, the Open Archives Initiative is currently an organization and an effort explicitly in transition, and is committed to exploring and enabling this new and broader range of applications. As scientists around the world gain greater knowledge of the scope of applicability of the underlying technology and standards being developed, and begin to understand the structure and culture of the various adopter communities, both the mission and organization of the Open Archives Initiative will continue to evolve..

Policy decisions about the Open Archives Initiative are made by a Steering Committee. The interoperability infrastructure was developed by a technical committee, which continues to advise on the infrastructure as experience with it develops. Herbert Van de Sompel and Carl Lagoze are responsible for coordination of OAI activities, which are centred at Cornell University. The mail address for OAI correspondence is <openarchives@openarchives.org>. The Open Archives Initiative is supported by the Digital Library Federation, Coalition for Networked Information, and National Science Foundation.

The OAI invites both data providers and service providers to participate in the interoperability framework that is defined in the Open Archives Metadata Harvesting Protocol. Information about the Open Archives Initiative is available at the OAI web site (http://www.openarchives.org).

The full-text physics archive, **arXive**, founded by Paul Ginsparg at Los Alomas in 1991 and now moved to Cornell University, is probably the oldest and the most prominent subject-specific e-print server. With more than fifteen mirror sites around the world including five in Asia (India, China, Japan, South Korea and Taiwan), one in Brazil and one in South Africa, this automated electronic archive covers research papers in physics, mathematics, nonlinear sciences, computational linguistics, and neuroscience. arXiv contains about 140,000 free full-text research papers, of which about a half are in astrophysics and high energy physics. This pioneering effort is easily one of the most innovative and successful experiments to date in scholarly communication. Another physics database is the **SPIRES HEP** literature database, where one can search more than 450,000 high-energy physics related articles, including journal papers, preprints, e-prints, technical reports, conference papers and theses, comprehensively indexed by the SLAC and DESY libraries since 1974. **The Digital Library for Physics, Astrophysics, and Instrumentation** [http://adswww.harvard.edu], hosted by the Harvard-Smithsonian Centre for Astrophysics and funded by NASA, maintains four bibliographic databases containing more than 2.6 million records. **ResearchIndex** (or **CiteSeer**), the full-text archives for computer science, founded by Steve Lawrence of NEC Research, Princeton, NJ, is a scientific literature digital library that aims to improve the dissemination and feedback of scientific literature, and to provide improvements in functionality, usability, availability, cost, comprehensiveness, efficiency, and timeliness. Rather than creating just another digital library, ResearchIndex provides algorithms, techniques, and software that can be used in other digital libraries. ResearchIndex indexes Postscript and PDF research articles on the Web. It uses ACI to autonomously create a citation index that can be used for literature search and evaluation. Compared to traditional citation indices, ACI provides improvements in cost, availability, comprehensiveness, efficiency, and timeliness. ResearchIndex uses search engines and crawling to efficiently locate papers on the Web. Authors need not submit thair papers in any special format. It is the largest e-print archive with more than 400,000 papers. The full source code of ResearchIndex is available at no cost for non-commercial use. **Cogprints**, the archive for cognitive sciences founded by Steve Harnad at Southampton

University, UK, is an electronic archive for papers in any area of Psychology, Neuroscience, and Linguistics, and many areas of Computer Science (e.g., artificial intelligence, robotics, vison, learning, speech, neural networks), Philosophy (e.g., mind, language, knowledge, science, logic), Biology (e.g., ethology, behavioral ecology, sociobiology, behaviour genetics, evolutionary theory), Medicine (e.g., Psychiatry, Neurology, human genetics, Imaging), Anthropology (e.g., primatology, cognitive ethnology, archeology, paleontology), as well as any other portions of the physical, social and mathematical sciences that are pertinent to the study of cognition. It runs on EPrints open archive software, a freely distributable archive system available from EPrints.org. The open archives interoperability is achieved using open archives software developed at Cornell university. **Clinmed** [clinmed.netprints.org], launched in December 1999 as a collaborative venture of the BMJ Publishing Group and Stanford University Libraries' HighWire Press, is a website that provides a place for authors to archive their completed original research into clinical medicine and health - before, during, or after peer review by other agencies. All articles fulfilling certain minimal conditions will be posted, usually within 24 hours of receipt. There are similar services in economics (RePEc) and computing (CoRR).

Electronic e-prints do not aim merely to capture the articles; it is far more than a simple electronic reproduction of what would appear in print journals. E-print publication on the web offers numerous value-added elements, such as multi-media, data sets, as well as contextual links to other documents referred to in a paper and to databases. Indeed, the document linking advantage is being exploited by digital libraries, commercial aggregators of journals and secondary service providers such as ISI and Chemical Abstracts Service. In the very near future, the print versions of journals will not be the true archivers. The e-print archives, as both the data and the access systems can be mirrored in several locations around the world, offer in-built insurance against possible loss of archived material due to unforeseen calamities (such as natural disasters or system failures at any one location). For some reason, e-print archives in fields other than physics and computer science are not growing fast enough despite some well-meaning efforts. A commercial publisher has established ChemWeb, a preprint server for chemistry, but it is not yet as popular as the physics preprint servers.

Developing country scientists should use the existing archives to disseminate their work as well as to learn about the work of others. They may also etablish national level e-pint servers, especially in fields such as agriculture and health sciences.

PubMedCentral

<http://www.pubmedcentral.gov>

PubMed Central is a digital archive of life sciences journal literature, developed and managed by the National Center for Biotechnology Information (NCBI) at the U.S. National Library of Medicine

(NLM). With PubMed Central, NCBI is taking the lead in preserving and maintaining open access to the electronic literature, just as NLM has done for decades with the printed biomedical literature. PubMed Central aims to fill the role of a world class library in the digital age. It is not, and has no intention of becoming, a journal publisher. Access to PubMed Central is free and unrestricted.

PubMed Central follows in the footsteps of other highly successful and useful services that NCBI has developed for the worldwide scientific community: GenBank, the genetic sequence data repository, and PubMed, the database of citations and abstracts to biomedical and other life science journal literature. GenBank, and the tools provided by NCBI for searching and manipulating its contents, have been a boon to molecular biologists and have helped advance developments in the field. PubMed (which encompasses Medline) is a good database for researchers and clinicians alike, to locate relevant articles and, in many cases, link directly to a publisher's site for the full text.

Participation by publishers in PubMed Central (PMC) is voluntary, although participating journals must meet certain editorial standards. A participating journal is expected to include all its peer reviewed primary research articles in PMC. It may, at its discretion, also deposit other content such as review articles, essays, and editorials. Review journals, and similar publications that have no primary research articles, are also invited to include their contents in PMC. However, primary research papers without peer review are not accepted.

A journal may deposit its material in PMC and make it available for public release as soon as it is published, or it may delay release in PMC for a specified period after initial publication. Copyright remains with the journal publisher or with individual authors, whichever is applicable. The value of PubMed Central, in addition to its role as an archive, lies in what can be done when data from diverse sources is stored in a common format in a single repository. GenBank has proven the advantages of collecting DNA sequences in a central repository with a common format. You get more rapid searching, manipulation, and cross-linking of the complete collection, and all the benefits that derive from that. Similarly, with a well populated PubMed Central archive, one will be able to quickly search the entire body of full-text literature and locate relevant material regardless of its source. It also becomes economical and practical to develop tools to integrate the literature with a variety of other information resources such as sequence databases and other factual databases that are available to scientists, clinicians and everyone else interested in the life sciences. The intentional and serendipitous discoveries that such links might foster excite us and stimulate us to move forward.

Many journals already have online publishing operations and there is a growing tendency to publish material online only, to the exclusion of print. This literature must be preserved in a form that ensures open access to it over the longer term. This is what NCBI has undertaken to do. *Scientists from developing countries should encourage all journals to join such efforts.*

Journals

There are a number of journals and archives which are now available free on the web. The most prominent among the journals is *BMJ*, one of the earliest to be made available free. Indeed the electronic version of *BMJ* carries additional material which could not be accommodated in the print version for want of space. **BioMedCentral** [http://www.biomedcentral.com] publishs more than 50 journals, provides free access to all papers and encourages new free journals. It charges a handling charge of $500/article from the authors or their institutions (except those from the developing world and some other authors for whom the charge is waived). Full text of more than 750 medical journals are available free on the web, and the number is increasing (For a list of the journals, please visit <www.freemedicaljournals.com>). Association of Research Libraries, USA, has published a *Directory of Electronic journals*, which lists several hundred titles that provide free access. Unfortunately, this directory is available only in print form. ARL should be persuaded to make it available in electronic form.

Open Society Institute (Soros Foundation) [http://www.soros.org/openaccess], founded by the millionaire George Soros, has issued a statement advocating open access and has provided $3 million over 3 years for projects supporting 'alternative' journals and open archiving initiatives.

The African Virtual University is a “university without walls” that uses modern ICTs to give institutions in sub-Saharan Africa direct access to some high quality learning resources. It provides students and professionals in 17 countries free email accounts and access to an online digital library with over 1,000 full-text journals.

Non-profit initiatives

There are a few non-profit publishers/distributors of developing country journals and information. These include Bioline International [http://www.bioline.org.br], which hosts electronic versions of many developing country journals (most of them at a modest subscription fee); International Network for the Availability of Scientific Publications, or INASP [http://www.inasp.info/index.html], a co-operative network of partners whose mission is to enhance the flow of information within and between countries, especially those with less developed systems of publication and dissemination; SciELO [http://www.scielo.org], which hosts more than 80 journals published in Latin American countries, such as Brazil, Chile, Costa Rica and Cuba, and Spain; and African Journals Online or AJOL [http://www.inasp.info/ajol/index.html], that provides free online access to titles and abstracts of more than 60 African journals and full text on request.

HINARI (Health Internet) [http://www.healthinternetwork.org], a UN/WHO initiative aims to provide commercial medical journals free to licensed countries in the developing world. PERI (Programme for the Enhancement of Research Information) [http://www.inasp.info/peri/index.html], promoted by the INASP is a programme for the support to information production, access and dissemination for research partners in developing and transitional countries utilising new information and communication technologies (ICTs).

The Electronic Publishing Trust for Development (EPT) was established in 1996 to facilitate open access to the world's scholarly literature and to support the electronic publication of reviewed bioscience journals from countries experiencing difficulties with traditional publication. The main activities of the EPT are to provide awareness of the benefits of electronic publishing, transfer e-publishing technology through training and online resources, provide management and distribution support, and support open access initiatives and make them known to developing country scientists and publishers.

What Needs to be Done?

What we want to achieve is to make scientific and technical information flow freely and be accessible at affordable costs to researchers and students everywhere in the world. A kind of enlightened socialism as it were for scientific knowledge. To be honest, this could only be an ideal - the direction in which we should move. Achieving this goal would necessarily mean exploring many possibilities. First, we should try to facilitate access to all the content (scientific and technical journal papers, reports, theses, conference papers, bibliographic, factual and full-text information, etc.); second, we should ensure all potential users of this content have access to the technological tools to access it (such as high bandwidth Internet connection); third, we should continue with our efforts to evolve standards and norms, including research into better ways of doing things, that will enhance the ease of use and value of the content; fourth we should build organizational structures that would ensure the long-term survival of the entire system.

As we saw in the previous section, there have been many efforts to enhance free and low-cost access to content of different kinds. Many journals such as *BMJ* are available absolutely at no cost to readers in the developing world. Three is a whole list of Free Medical Journals that are available free on the Web. The Indian Academy of Sciences allows free access to several of its journals, but one cannot access them as quickly as one can access *BMJ*. [The Academy should host its journals on a far more powerful server.] A number of journals are available for free access a few months - ranging from six to twenty-four months - after publication. Many high-impact journals are given such delayed access by High Wire Press of Stanford University. Parts of certain journals such as *The Economist* and *The New Scientist* are available free on the Web.

Scientists in developing countries and organisations that care for their welfare such as the Third World Academy of Science and the Inter Aacdemy Panel should bring pressure on publishers to make electronic access to their journals free or at least make them freely available a few months after publication. They should support the Public Library of Science movement.

Unfortunately, several well-established publishers would not like to lose their stranglehold on the scholarly journals market and would do everything to scuttle the open source movement. For example Ingenta, a leading for-profit aggregator of electronic journals has recently succeeded in roping in half a dozen champions of the open source movement to be on their advisory board!

A few months ago the Director General of WHO Dr Gro Harlem Brundtland and the editor of *BMJ* Dr Richard Smith negotiated a deal with half a dozen leading publishers of biomedical journal, responsible for publishing about 1,500 journals, to make their journals freely accessible to public institutions, universities and hospitals in more than a hundred developing countries. Subsequently more than twenty other publishers were persuaded to join and the number of journal titles freely available to clients in the Third World rose to about 2000. The main criterion for selection of countries was per capita GDP of less than $1,000. What really happened was that the publishers did not extend the benefit to several countries that met this criterion (e.g. India, Pakistan and Bangladesh), on the grounds that they already have many subscribers in those countries and they would lose business! In essence, they are willing to give free access to their journals to countries where there are hardly any users. A clear case of having the cake and eating it too. WHO and others interested should renogotiate the terms and enable all developing countries to gain free access to these journals.

Organizations such as FAO and ISNAR may take the lead for working out a similar arrangement for developing country institutions to gain free access to agricultural (and related) journals. The Inter Academy Panel, formed by over 80 Science Academies of the world, can lend its support to such a move.

It is not just the commercial publishers who are making it difficult for developing country scientists to gain free access to information. Even some society publishers are unwilling to throw open access to their journals, largely because subscription to their journals is their major source of income. What is more, recently *Science*, the weekly journal of the American Association for the Advancement of Science, published the draft rice genome sequence (of the *japonica* strain of rice) by scientists from the Swiss agrochemical company Syngenta without requiring the company to deposit its data in a public database such as GenBank! 'Foul' cried many scientists, but AAAS couldn't care less. In the same issue a Chinese-led team of academics had published a blueprint of the *indica* strain of rice and the map is available in GenBank. This is not the first time *Science* has allowed private interest to score over public good. Earlier, it allowed Celera to withhold data on the human genome sequence. Scientists everywhere, and especially those in the developing world, should do all they could to persuade *Science* and AAAS (and other organizations) not to sacrifice the interest of 'public good' at the altar of commercial interests.

The National Academy of Sciences, USA, is a model for other societies and academies. Not only the Academy's *Proceedings* but also its entire collection of over 2,000 reports are available free on the Web to developing country users. Indeed, Prof. Bruce Alberts, the President of NAS, is a great champion of the cause of science and technology in developing countries. He played an important role in founding the Inter Aacdemy Panel and the Inter Academy Council. He was largely responsible for several programmes aimed to help science in the developing countries. In his Presidential address at the 136th Annual Meeting of the Academy, Alberts suggested the following two-part strategy:

> Connecting all scientists to the World Wide Web, where necessary by providing subsidized Internet access through commercial satellite networks, and
>
> Taking responsibility for generating a rich array of scientifically validated knowledge resources, made available free on the Web, in preparation for a time when universal Internet access for scientists is achieved in both developing and industrialized nations.

Both of these are excellent suggestions. Not only do we need useful content to be available free on the Web, but we also need the technology in place to take advantage of the content. *A concerted effort should be mounted to persuade philanthropic foundations and donor agencies concerned with higher education and research to donate funds to make available PCs and high bandwidth Internet connections to researchers and libraries in developing countries.* The concerned governments should make things easy for the spread of ICTs among university and research institutions.

There is a great need for building awareness among Third World researchers and research managers about electronic journals, open archives, benefits of networking nd so on. A few months ago the Indian Academy of Sciences held two workshops on electronic publishing with help from the Electronic Publishing Trust, IDRC and INASP. Evangelists like Steve Harnad should be taken round important centres of research in the Third World and asked to address scientists and scholars. A reader on the advantages of going electronic and current developments must be produced and circulated widely. Librarians in the Third World should be given special training programmes to play their role of information intermediaries in the changed circumstances. In short, the transition from print-based access to electronic information access in the Third world should be facilitated by lectures, workshops and training programmes as well as through provision of the technical backup.

While agencies such as EPT and INASP can help with the training programmes, organizations such as IAP, IAC and NAS can persuade the scientific communities and the governments in the Third World to overcome any inertia or barriers to make the transition. Donor agencies such as IDRC and the Soros Foundation can make the necessary investments to make the transition to happen soon. If all this can happen, then access to information for research will truly become democratic and the divide between the rich and the poor would be considerably reduced.

Acknowledgement

I am grateful to Brent Herbert-Copeley of IDRC for asking me to think about these issues.

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Table 1. Leading contributors to the literature of science [Data from *SCI*]

	Country	*SCI* 2000	*SCI* 1998
		Number of papers	
1	USA	262892	261826
2	JAPAN	68056	67568
3	UK	63972	62454
4	GERMANY	63365	64184
5	FRANCE	44990	45571
6	CANADA	31929	31166
7	ITALY	31673	30936
8	RUSSIA	23041	22824
9	P R CHINA	22061	14610
10	SPAIN	20546	19796
11	AUSTRALIA	19067	18404
12	NETHERLANDS	18826	18581
13	SWEDEN	14278	14197
14	SWITZERLAND	13828	13418
15	INDIA	12127	12128
16	SOUTH KOREA	12013	9444

Table 2. Number of papers published by five selected countries as seen from *SCI* over two decades

SCI	INDIA	CHINA	ISRAEL	SOUTH KOREA	BRAZIL
2000	12127	22061	9292	12013	9565
1999	12521	17138	9241	10918	9083
1998	12128	14610	9544	9444	7917
1997	11067	12630	8938	7728	6954
1996	11177	10152	8338	6227	5895
1995	11084	9713	8141	5125	5289
1994	11319	8226	7787	3684	4381
1993	10978	8087	7563	4318	4043
1992	11160	7630	6755	2248	3946
1991	10468	6630	6206	1818	3438
1990	10103	6509	6211	1448	2973
1989	10426	5491	6262	1332	2697
1988	10208	5312	6861	1075	2492
1987	10239	4048	6948	944	2859
1986	10854	3678	6729	773	2951
1985	11222	3238	6792	664	2511
1984	10600	2537	5570	440	1915
1983	12059	2974	6236	442	2248
1982	12124	2592	6058	321	2306
1981	13119	1544	5560	254	2374
1980	14983	924	5733	175	2215

Table 3. Percent share of world research in different fields for selected countries as seen from different international databases

Research share in	TB [*PubMed* [1990- 1999]	CVD	Diabetes	New biology [*BBCI* 2000]	Mathematics [*Mathsci* 2000]	Chemistry [*CA* 2001]	All science [*SCI* 2000]
India, %	5.34	0.66	1.11	1.35	2.02	2.5	1.55
China, %	1.11	1.04	0.63	2.03	10.35	9.8	2.83

TB = Tuberculosis. CVD = Cardiovascular diseases.
Source: Arunachalam & Gunasekaran, *Current Science*, 2002, Vol. 82 (No. 8), 933 – 947.

Table 4. Contribution to the world literature of tuberculosis of different countries and percent share of incidence of TB

	No. of papers*	% world share in research [A]	% world share in tuberculosis [B][+]	Ratio A/B
World	9796			
USA	3194	32.6	0.19	171.6
UK	1311	13.4	0.08	167.3
G7	6107	62.3	1.14	54.7
EU-15	3563	36.4	1.57	23.2
Nordic countries	284	2.9	0.03	96.7
Australia	175	1.8	0.02	89.5
Israel	50	0.5	0.01	51.0
India	565	5.8	21.68	0.27
China	50	0.5	16.09	0.03
Brazil	116	1.2	1.40	0.84
Mexico	85	0.9	0.44	1.98
South Africa	393	4.0	2.46	1.63
Kenya	40	0.4	1.45	0.28

*Data from *Science Citation Index* 1998 [CD-ROM version]
[+]Calculated from the data for the year 1999 provided by WHO, Global Tuberculosis Control, WHO Report 2001
Source: Arunachalam & Gunasekaran, *Current Science*, 2002, Vol. 82 (No. 8), 933 – 947.

Table 5. Number of papers co-authored by scientists from two rich [G7 and EU] countries*. [Data from SCI 1998]

	No. of papers	JP	GB	DE	FR	CA	IT	ES	NL	SE	BE	DK	AT	FI	GR	PT	IE
US	199,980	4494	5595	5931	3774	4794	3063	1444	1878	1551	909	972	651	660	401	201	270
JP	60,721		980	1094	575	555	405	154	292	287	113	115	90	117	32	16	24
GB	57,349			2531	2070	997	1531	1084	1242	810	599	778	321	321	351	298	368
DE	54,676				2309	739	1574	831	1245	741	589	578	909	367	303	139	112
FR	40,594					907	1669	1247	786	502	974	353	275	240	269	220	87
CA	26,094						404	220	292	251	161	162	76	114	58	23	35
IT	26,081							789	685	378	375	298	245	210	184	109	79
ES	17,521								409	223	261	230	134	167	110	154	47
NL	15,761									373	642	276	169	183	93	104	54
SE	12,658										212	501	104	429	66	71	41
BE	8,131											127	79	103	71	60	28
DK	6,780												106	177	95	60	29
AT	5,687													67	71	33	18
FI	5,676														41	34	12
GR	3,468															41	6
PT	1,984																15
IE	1,984																

* In some papers there may be authors from more than two countries. Country abbreviations used are two-letter ISO country codes

Table 6. Number of papers co-authored by authors from Asian countries with authors from different countries [Data from SCI 1998]

	Collaborating countries		IN	CN	JP	KR	TW	HK	SG	TH	MY	ID	PH
A	Canada	(26094)	88	195	555	92	67	83	24	13	8	17	11
	Japan	(60721)	195	627		416	155	38	43	89	25	39	42
	USA	(199980)	809	1216	4494	1216	725	344	161	166	28	63	58
B	France	(40594)	219	244	575	125	58	16	10	17	7	18	11
	Germany	(54676)	300	485	1094	167	98	50	12	28	4	30	11
	Italy	(26081)	132	184	405	109	54	12	4	6	8	4	0
	United Kingdom	(57349)	232	368	980	117	76	123	81	79	69	16	16
C	Austria	(5687)	9	67	90	34	5	2	1	9	1	1	0
	Belgium	(8131)	32	50	113	11	10	6	12	5	3	5	6
	Denmark	(6780)	21	59	115	37	7	6	4	13	3	0	4
	Finland	(5676)	44	43	117	27	25	5	4	5	3	1	2
	Greece	(3468)	5	41	32	30	0	0	1	0	0	0	0
	Ireland	(1984)	2	9	24	3	1	0	3	0	1	1	0
	Netherlands	(15761)	59	107	292	55	37	14	4	15	5	26	9
	Portugal	(1984)	8	19	16	0	3	1	0	1	0	1	0
	Spain	(17521)	73	98	154	80	30	7	4	5	0	0	6
	Sweden	(12658)	48	81	287	21	12	12	13	6	5	4	1
D	Australia	(16467)	80	171	397	48	43	76	63	32	26	40	15
	Czech Republic	(3222)	12	10	97	3	2	7	0	1	3	0	1
	Hungary	(3134)	45	40	139	28	25	3	1	3	0	0	2
	Iceland	(267)	0	0	9	0	1	0	0	0	0	0	0
	Mexico	(3377)	39	17	46	22	1	3	0	5	1	2	4
	New Zealand	(3493)	10	22	72	5	4	11	9	3	1	3	1
	Norway	(3918)	12	19	71	4	2	1	5	5	1	3	1
	Poland	(6705)	42	24	180	46	3	4	0	1	1	2	1
	Switzerland	(11677)	76	97	293	69	52	12	5	18	0	5	2
	Turkey	(3404)	6	3	29	4	1	0	0	0	1	0	0
E	Indonesia	(266)	3	9	39	3	3	2	0	10	5		5
	Malaysia	(538)	27	15	25	4	2	8	22	13		5	2
	Philippines	(266)	4	17	42	8	7	4	4	6	2	5	
	Thailand	(774)	8	5	89	7	5	7	3		13	10	6
F	Singapore	(1892)	10	105	43	3	27	30		3	22	0	4
G	Hong Kong	(3210)	17	415	38	0	45		30	7	8	2	4
	South Korea	(8234)	68	142	416		52	0	3	7	4	3	8
	Taiwan	(7113)	38	101	155	52		45	27	5	2	3	7
H	Bangladesh	(201)	16	1	20	0	0	0	0	0	1	2	1
	China	(13878)	71		627	142	101	415	105	5	15	9	17
	India	(11437)		71	195	68	38	17	10	8	27	3	4
	Pakistan	(379)	2	2	12	2	1	3	2	2	0	1	1
	Sri Lanka	(110)	2	0	4	0	0	1	0	2	0	1	2
I	Kenya	(421)	6	3	12	0	0	0	0	1	0	2	1
	Nigeria	(470)	5	3	1	1	0	0	0	0	0	1	0
	South Africa	(2777)	15	5	39	2	2	6	4	1	1	1	0
J	Argentina	(3229)	23	8	25	22	0	1	1	5	1	0	2
	Brazil	(6597)	52	37	94	26	2	3	1	4	1	2	1
	Chile	(1369)	7	9	9	4	1	3	1	3	0	1	4
	Cuba	(350)	2	3	2	0	1	1	1	8	0	1	1
	Peru	(155)	1	0	1	1	0	0	0	1	0	2	3
	Venezuela	(702)	3	3	4	0	0	0	0	1	0	0	2
K	Israel	(7523)	18	16	148	31	13	8	5	4	1	0	0

A + B = G7, B + C = EU, A + B + C + D = OECD, E + F = ASEAN, F + G = Tigers
E + F + G + H = Asia I = Africa, J = Latin America, K = Israel

Table 7. Number of papers coauthored by scientist from some African and Latin American countries*
[Data from *SCI* 1998]

	No. of papers	MX	AR	CL	VE	CU	ZA
BR	6597	69	136	60	18	21	15
MX	3377		61	25	15	50	8
AR	3229			45	14	14	8
CL	1369				17	6	6
VE	702					2	0
CU	350						0
ZA	2777						

* In some papers there may be authors from more than two countries
Country abbreviations used are two-letter ISO country codes