International Science—An Overview

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Summary. Scientific projects that succeed as international cooperative efforts are those related to subjects that transcend national frontiers, are costly, have long-range objectives rather than short-term commercial aims, and correspond with the political objectives of the countries involved. Yet the best context for all of science is the global community, which is also the best hope for humanity. The global community is still generations away and scientists must continue to work for it, by seeking the international dimensions of science as individuals and participating in governmental as well as nongovernmental international scientific organizations.

Of all the communities on this planet that have sought to communicate in a positive fashion beyond tribal or parochial boundaries, the international scientific community must surely be acknowledged as one of the most successful. Generally speaking, during the past two centuries the citizens of the international scientific community have achieved a harmonious state, where political, racial, linguistic, economic, or other differences have not marred their common purpose, their mutual understanding and assistance, their universal agreement on terms, meanings, criteria, procedures, standards, acknowledgment, and even a certain liturgy of communication, perfected by high priests such as Karl K. Darrow. Quarrels and disagreements proceed according to established and acknowledged rules, as in the days of an earlier chivalry; they are usually brief, and produce no losers, but only honored adversaries.

The international scientific community is one of rigorous standards associated with difficult labor, yet it is of much understanding and good manners, a society in which men and women coexist with others of such different backgrounds and ideologies as have often rent communities intent on other pursuits. It has probably been the most successful of mankind's attempts to build a global society. I say has been, because the dangers of its frontiers are probably rather greater than usual today. The community has grown enormously in the last generation, and its traditions have not been perfectly transmitted to all. Science has interested the businessman, the economist, the sociologist, the politician; all of these and other persuasions have been getting involved with science, and not all of them are well considered for the harmonious communities that *they* have established on the planet. Science is influencing more and more facets of the scientist's life other than the intellectual, and in these other roles scientists sometimes lose the viewpoint that their own international community gives them. But by and large, the international community of science must be respected for its achievements and as a model of association in dignity of free people.

Role of International Organizations

About 20 years ago a few hundred of us from various countries had been having rather impromptu meetings every 2 or 3 years to discuss atomic and electronic collisions, and it was suggested that the meetings should be organized more formally, probably under the sponsorship of the International Union of Pure and Applied Physics (IUPAP), to ensure the presence of our Eastern colleagues. Wade Fite mused on this and said: "Yes, I guess the time has come to organize and get bogged down." Organized we became, the bogging down was minimized, and this has happened to thousands of groups around the world. Today there are over 300 international organizations of scientists in the world, any one of which, like IUPAP, may sponsor hundreds of groups like our little atomic collisions coterie.

The first such organization on record is that of the Universal Society of Ophthalmology, founded in 1861 in Paris, although internationally organized activities such as the sky chart project of Bessel in 1824 and the geomagnetic measurements promoted by Gauss in 1830 are but examples of scientific cooperation that is rooted in the deeps of centuries past. The success of groups like the Bureau International des Poids et Mesures (1875) began to interest governments, and after the turn of the century the foundations of the great modern international scientific organizations came into being.

These are clustered into several groupings. One is the large family composing the International Council of Scientific Unions or ICSU, an international nongovernmental scientific organization. ICSU is composed of about 18 scientific unions, each of which groups together most of the world's practitioners of a given discipline—astronomy, chemistry, geophysics, and so on. The role of a given scientist in his or her union (*1*) varies from country to country. The role of the unions is to rule on symbols, nomenclature, and units, set standards, organize international conferences, publish journals, undertake special projects, and face up to special problems. In our current political climate, union sponsorship of a conference is essential to ensure participation by Eastern scientists, and the safeguarding of the free circulation of scientists is now one of the unions' main preoccupations. The International Council, in addition, organizes great global projects, such as the International Geophysical Year, the Year of the Quiet Sun, and the Global Atmospheric Research Program. It is currently concerned with the problem of applying science usefully and with discernment to the development of Third World countries.

Another grouping of international scientists corresponds to what are sometimes referred to as the professional societies. The World Federation of Engineering Organizations, the International Council for Medical Sciences, and the World Energy Conference carry out, in their fields, activities analogous to those of ICSU in the disciplinary sciences.

Yet another grouping corresponds to formal governmental agreements, and is centered about the United Nations. The U.N. Educational, Scientific, and Cultural Organization and the Food and Agriculture Organization, for example,

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all in turn encompass myriads of programs and suborganizations. These government-associated agencies tend to be slow-moving, and have often been used as political forums. However, much has been accomplished, particularly in assistance programs.

In some ways analogous to the U.N. structures are those of several other government-sponsored groupings: those of the North Atlantic Treaty Organization, of the Warsaw pact countries, of the European Community, of the British Commonwealth, of the various Pan American organizations, of the several African associations, of the corresponding Asian groups, and those of Latin America. There are hundreds and hundreds of these organizations.

One characteristic that all of these organizations have in common is chronic underfunding. They rely heavily on the voluntary contributions of time, organizational talent, and project contributions of tens of thousands of bench scientists and engineers. The total UNESCO budget, one of the largest, was about $150 million in 1980 including about $40 million for its natural science programs. The ICSU yearly budget is only $1.8 million. The IUPAP budget is—look closely—$100,000 per year. By comparison, the total world spending on armaments is estimated as $500 billion in 1979, which represents $57 million every hour, every day of the year. The UNESCO budget for science is then worth only about 40 minutes of the world's military spending.

Science and Technology in International Assistance

An important aspect of international science and technology is the resultant transfer of technical ability between nations, which improves the potential of each for further development. The greatest results might be expected of such transfer to developing countries which on the one hand have the greatest need, and on the other hand have untapped human resources that must some day add their contribution to the world pool. However, present world activity has not addressed this challenge adequately.

It is now common knowledge that many developing countries are sinking more and more deeply into economic distress, and this because of well-known circumstances: (i) increasing populations which are outstripping the gains from improved technology including new, high-yield varieties of food crops; (ii) the increasing cost of oil, which is taking ever greater fractions of poor countries' hard currencies; (iii) greater shortage of foodstuffs and greater dependence on processed foreign supplies; (iv) progressive deforestation which is causing soil erosion and silting up of rivers and reservoirs; and (v) public health problems, notably parasitic diseases.

The solution to many of these problems can only come from research and development. But global R & D resources are concentrated in a small number of countries (*2*). It is estimated that 20 percent of the technically advanced peoples carry out 95 percent of the world's R & D; in fact only six countries are responsible for about 90 percent of it. One natural consequence is that large resources are allocated to research on relatively restricted diseases such as cancer while comparatively little is spent on widespread parasitic diseases. This is not to say that cancer research should be curtailed, but that other health problems affecting vastly greater numbers of people should be given more attention.

Of the $4.5 billion spent on agricultural research, only about $225 million is allocated to developing countries.

According to the U.N. *Statistical Yearbook 1978*, the total amount spent on development of Third World countries in 1977 was $14.5 billion, of which $9.2 billion was the result of various bilateral agreements, and $4.6 billion was affected to various multilateral arrangements, such as the U.N. Development Program and UNESCO. The various U.N. and other global international agencies spent about $0.8 billion on various technical aid programs.

Against the background of world needs and of expenses in other areas, these impressive-sounding amounts are pitiful, and in some ways are symbolic rather than effective. Most industrialized countries spend a very small fraction of their gross national product on aid to their developing neighbors. The approximately $15 billion which is thus earmarked appears miserly when compared with the $500 billion spent yearly on armaments. It is not to the credit of many developing countries either that of the meager 5 percent of the world expenditure on R & D that they control, they too spend 80 percent of it on armament research.

These factors greatly exercised many of those who were present at the mammoth United Nations Conference on Science and Technology for Development (UNCSTD) held in Vienna in 1979. Here many of the developing countries, grouped under the aegis of the Committee of 77, called for the launching of more effective R & D transfer programs both to accelerate the development of Third World countries and to begin channeling their own potential contributions into the world stream.

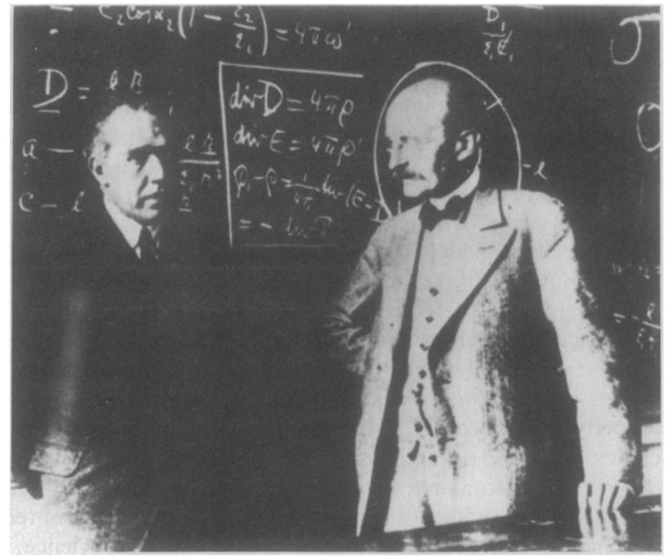
One result was the adoption of a resolution to which most of the Western industrialized countries adhered, to create a fund of $250 million for a 2-year action program. A controversy developed as to the mechanisms by which these funds would be disbursed, which has not been fully resolved. In fact, little of the money has been subscribed, and the whole exercise might be said to have bogged down. In the context of the need and the urgency of the problem, and even the self-interest of all concerned, the delay in implementing the weak UNCSTD resolutions is a tragedy and a scandal.

In Canada, although the overall national effort in scientific and technological aid to developing countries is scarcely noteworthy, one mechanism that we have developed is functioning: this is the International Development Research Centre (IDRC) (*3*). This expends all of its funds *in* developing countries on R & D projects selected *with* these countries. The IDRC governing council, in fact, has a majority of members from the developing states, and these consider it to be a model of effective structure. Sweden has adopted a similar approach, and one of the interesting announcements made at Vienna was that the United States would also be setting up an agency with comparable features.

Another group of institutions that has done much to foster the development of world science is composed of charitable and philanthropic foundations such as the Ford or the Rockefeller foundations. In the sector of agricultural research, these foundations have played a crucial role in contributing to the creation of a network of international agricultural research centers dealing with the problems of tropical and semitropical countries. Two of their outstanding achievements are the International Rice Research Institute in the Philippines and the International Center for Maize and Wheat Improvement in Mexico. At present, an international consortium, the Consultative Group for International Agricultural Research or CGIAR, which is under the aegis of the World Bank, the United Nations, and the Food and Agriculture Organization, is financing the activities of some 13 international research centers with a combined budget of nearly $120 million, a small fraction of the total spent on international projects.

The transfer of science and technology to Third World countries is beyond doubt the most pressing dossier in international science today. Every scientific agency should be concerned with it, and the excuse of it not being mandated can scarcely apply before a problem of this magnitude. Although it is not part of its explicit mandate, the National Research Council of Canada is establishing a Third World desk to cooperate with IDRC and the Canadian International Development Agency, and hopes to expand considerably the activities in which we have developed expertise, such as the Technonet-Asia program which we carried out in Southeast Asia at the request of IDRC, and which is now an autonomous and successful service.

I also here suggest that the AAAS, with its rich human resources, could be a powerful force for the analysis of these problems, and a puissant lobby, both nationally and internationally, for their solution. A Third World desk at the AAAS would be a most cheering development.



Niels Bohr and Max Planck. Niels Bohr refused the presidency of IUPAP because former enemies of his country were not being admitted to international scientific meetings. [AIP Niels Bohr Library; Margrethe Bohr Collection]

Present Level of International Science

From a broader point of view, one of the difficult but interesting aspects of international science is quantifying it. To speak of the level of international science is to venture into a realm of many ad hoc definitions and classifications. Numerous surveys and studies have been made, usually on very particular points and with incomplete data. The overall impression that one gets from considering many of these is that the international dimensions of science are of such a level that the progress of science would be severely crippled if these dimensions were absent.

The first point to note is that the greater part of the international dimension of science is no doubt provided by the individual scientists, who meet in conferences, exchange correspondence and, above all, read each other's work in the journals and abstracts. The vast amount of effort that has gone into the translation of journals and the rationalizing of abstracting services is witness to the importance of these channels. Some reviews of this activity (*4–6*) provide interesting statistics which are, however, difficult to translate into a level of scientific activity per se.

A related but still indirect consideration concerns the effective co-working of scientists, as evidenced by coauthorship of papers. Frame and Carpenter (*4*) have studied this for 21 scientific communities, examining over 200,000 papers as reported in *Science Citation Index* for 1973. It turns out that about 1 paper in 30 is coauthored by scientists from different countries, the greatest such collaboration being achieved in space science and physics where, respectively, 4.4 and 4.2 percent of papers are internationally coauthored, the lowest rate being in clinical medicine and engineering, at about 1.5 percent. Coauthorship is greatest in the developing countries, and lowest in the Soviet Union. Some 4.4 percent of papers from the United States are coauthored from another country, while 10.4 percent of Canadian papers are so authored. Comparison of such studies with similar ones on coauthorship between institutions will eventually lead to a quantifying of this interesting parameter of the level of international science.

A third index of this level would presumably be its budget. Here again, ad hoc definitions abound. The total global R & D budget is estimated at $150 billion. However, more than a quarter of this (about $35 billion) is spent for military programs. From 5 to 10 percent of the remainder is usually spent by various governments on international projects, which might then be evaluated at about $8 billion to $10 billion, involving about 150,000 equivalent scientists. Here again the effort is not evenly distributed, as certain very expensive fields dominate the picture. Thus, fully 90 percent of Italy's international science budget is for the fields of space and nuclear energy; 60 percent of West Germany's is devoted to space projects. In fact, 95 percent of all of Western Europe's international budget for science is concentrated in three organizations: CERN, EURATOM, and ESRO (including ELDO). During the 1970's, this tended to decrease. The United Kingdom, for example, reduced its international budget from 8.2 percent of its R & D effort to 3.5 percent between 1965 and 1970. Evidently the concentration in three organizations leads to fluctuations.

Taken together, the coauthorship data and the budget data would imply in a preliminary way that about one scientist in ten is active in some international project or another, which one-third of the time leads to coauthorship.

Yet another index of international activity might be the number of organizations devoted to it. As I have indicated, there are over 300, and probably one scientist in two has been involved with one or another of them. Three hundred is a greater number of associations than is usually met with even in larger individual countries, which is another characteristic of science as practiced internationally.

The level of activity of international science is thus difficult to assess quantitatively but, according to a number of indices, it seems to correspond to our qualitative view of the subject as being one whose international dimension is an essential part of its nature.

Considerations Conducive to International Partnership

Although the individual scientist may seek the international dimension of science regardless of his or her discipline, the same is not true of nations. Certain circumstances are more conducive to collaboration than others, and, in a word, nations are prone to participate when they consider it to be to their advantage to do so. Statesmen are less altruistic than scientists. To take a simple example, nations will participate more readily in very long-term projects than in mission-oriented work (when their own commercial interests are involved). Thus, only 2.7 percent of the research budgets of countries that belong to the International Energy Agency is spent in collaboration.

I discuss here some of the considerations that many nations appear to consider as being conducive to international partnership.

To begin with, there are certain fields of science the measurements or data for which transcend national boundaries and impose collaboration if they are to be properly pursued at all. Such fields include standards, oceanography, meteorology, radioastronomy, and epidemiology. Thus the eradication of smallpox was made possible only by the concerted effort of many nations over a long period; even countries at war with each other continued to collaborate in this common purpose, another echo from chivalry, which greatly advanced this medical accomplishment.

In the field of physical standards such as length, mass, or electrical units, global coordination under such associations as the Bureau International des Poids et Mesures ensures uniform, consistent standards the world over.

Economic cost is another consideration which has inspired international partnership in science and technology. The research and development for the Concorde supersonic aircraft and for the less spectacular but more economically successful Airbus are examples. The development of fusion energy generators is beyond the means of any but the largest nations or consortia of nations, and in Europe the huge JET (Joint European Tokamak) project would be impossible were it not for a joint venture supported by many nations.

There is still some hope, in fact, that a truly global project in the field of fusion may be undertaken when the general political climate improves, and the INTOR (International Tokamak Reactor) may well hasten the moment when the world straightens out its energy difficulties.

A happy coincidence of scientific and commercial interests resulted in the Ariane space-launching facilities. A different but equally felicitous combination—this time of scientific and political interests—resulted in what is probably the world's finest optical telescope constructed by Canada and France in Hawaii.

Such ventures are rooted in successful cooperation in the field of nuclear and particle physics, where the accelerators required have for years been the scene of work by joint research teams, and have even been joint undertakings—for example, the successful CERN (European Commission for Nuclear Research) laboratory. Another root of such international collaboration is to be found in the evolution of scientific R & D in the United States which, for a long time, was the dominant element in most of the fields of research requiring global perspective. This status resulted from several decades of recognition of the importance of science, of the atmosphere of freedom which characterized the United States' scientific milieu, and of its willingness to invest substantial resources in it. The United States, with a variety of motives, some altruistic, also encouraged international cooperation and prepared the way for many of the current agreements.

As the resources and interest of other nations or groups of nations increase, the United States is finding it even more convenient to engage in international science. It is both urging organizations such as ICSU to increase their activities in the rather fundamental science fields, and accepting partners in areas of engineering and commercial interest. An example of this is the major space shuttle program which will open a new chapter in space science. Here Canada has been invited to participate and has designed and constructed the remote manipulator arm (now called the Canadarm) which, incorporated into the shuttle, will perform such tasks as depositing, reorienting, and recuperating satellites. Other countries are also associated with this venture and are preparing experiment modules which will be placed in the European Spacelab by the shuttle with the help of the Canadarm.

One may sum up by saying that a scientific project will more easily succeed as an international cooperative effort if it corresponds to a subject which transcends national frontiers, if it is costly, if it has long-range objectives rather than short-term commercial aims, and if it corresponds to a political objective of the countries involved. Those scientific and engineering lobbies interested in international cooperation would be wise to assemble all four elements into their projects when possible. I suppose that the easiest one to ensure is high cost.

Conclusion

Science's ever greater contributions to human affairs and its need for relatively massive resources for research have caused it to become more and more affected by national interests and political concerns. The best context for science is the global community, and not unrelated is the fact that the global community is also the best hope for the future of humanity. But the global community is still generations away. Scientists must work for it, patiently but with dedication. Their own international community is relatively strong, as we have seen, but it requires further strengthening, for it is an important deterrent to the potential of the $57 million per hour spent on armaments.

I have in my files an unpublished letter of Niels Bohr, who about 50 years ago refused the presidency of IUPAP because former enemies of his country were not being admitted to international scientific activities. He refused to take part in those which did not consciously seek the participation of all of humanity, without exception.

We can do no less (*7*).

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