Science International
A US view of its institutional needs

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Global science will benefit from better 'international market places' in which potential participants in international scientific cooperation can gather, trade information, and do business, should they choose. Problems with projects such as particle accelerators and space stations underscore the timeliness of institutional innovation. Changes should occur in both *non-governmental* infrastructure, which brings together the people with the ideas, and *intergovernmental* mechanisms, which convene people who control financial resources. A major international commission on international institutions for cooperation in scientific research should be formed to assess needs and to propose and build support for more efficient, capable, and reliable mechanisms.

The phrase 'Science International', which is the point of departure for this review, and happens also to be the name of the newsletter of the International Council of Scientific Unions, sounds stronger than the more common reference, 'international science'. Perhaps because Science International echoes the Socialist International, the phrase even sounds a little conspiratorial. It should. Science, worldwide, is a single cognitive formation. This statement has always been true. The locations of the clubhouses change. At one time the largest were in Athens and Alexandria, at another London and Leiden, now La Jolla and Geneva.

The process of systematic discovery of the elements of the periodic table that began in the eighteenth century graphically displays the cognitive unity of the international scientific community (Fig. 1). Chemists searching from Uppsala to Edinburgh, from Transylvania to Castile, and in the New World, functioned as one coherent, multinational entity.

The Republic of Science

So, scientists are dual citizens. These remarks focus on our citizenship of what Michael Polanyi more than 30 years ago called the Republic of Science.[2] What should be the institutions of our planetary republic? The health of the republic is always worth checking, but it is natural to wonder why someone would ask now from Science International's US subsidiary, its wealthiest, largest, and most capable. Three reasons dominate.

Cost

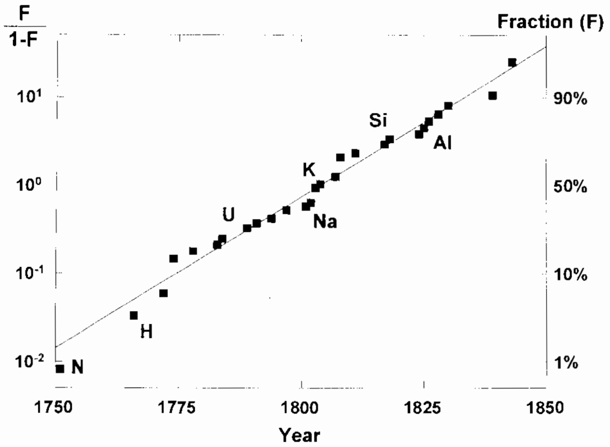
In some fields, research results are costing a great deal more, as particle physics and astronomy illustrate. Derek Price, the late, great, and usually prescient historian of science, conjectured that scientific results grow as the cube root of the expense of research (and that costs of science would increase as the square of the number of scientists).[3] Discouraging if true. The controversial Chubin study of the Office of Technology Assessment reported much smaller increases.[4] Science is a service industry, and let us hope that information technology will reduce the cost of its business, as it promises to do in many service sectors. If not, there exist deep reasons for concern. In any case, modern science needs the riches of the global economy (even as a modern economy needs science).

Conjunctural crisis

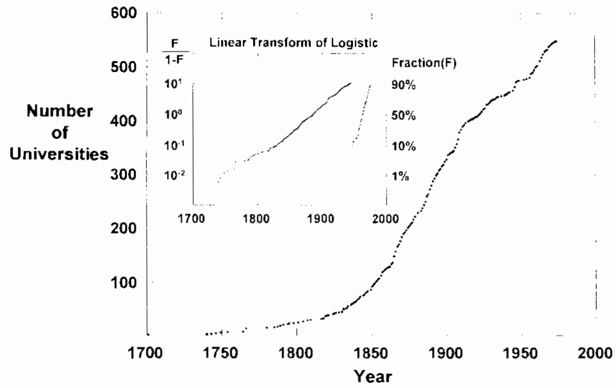
We are living through one of the periods of simultaneous economic, political, and technological fluctuation that profoundly restructure the world every 50 years or so. If the society shivers, science feels it, even if wrapped in a blanket. The Second World War and the Cold War drew or refigured a set of institutions that have been important for science. In the USA, these included the Atomic Energy Commission, Defense Advanced Research Projects Agency, National Aeronautics and Space Administration, and National Science Foundation. Internationally, the North Atlantic Treaty Organization (NATO), the Organization for Economic Cooperation and Development (OECD), and the International Atomic Energy Agency are obvious examples. As the missions of all these organisations come into question, science looks for new patrons and partners.

Overcapacity of US scientific infrastructure

It is unpopular to say so, but there is overcapacity in the US research and development establishment. The overcapacity does not seem to have created a competitive situation in which costs decline. (In the medical profession, increase in the supply of doctors seems to raise costs as each physician seeks an appropriately



1 Fraction of the set of about 50 stable chemical elements discovered from 1750 to 1850, plotted as a logistic growth function (in linear transform), with nitrogen (N), hydrogen (H), uranium (U), sodium (Na), potassium (K), silicon (Si), and aluminum (Al) identified: data from Ref. 1. Well before the phone, fax, and jet plane, the international scientific community behaved as one



2 Population of US universities plotted as a pair of logistic growth functions, with a small recent pulse surmounting an early large one: data from Ref. 5. Inset shows linear transform. The recent steep pulse has filled over 90% of its estimated niche. At such times of saturation, populations typically experience great stress

high income.) The three major performers of research all show overcapacity.

The easiest excess to recognise and accept is the \$20 000m set of *national laboratories*. It is hard to argue these now respond to felt needs or opportunities. The effort to relabel the integral fast reactor an environmental facility for incineration of hazardous waste shows the strain of adjustment.

Industry is usually criticised for underinvestment in research and development, but consider possible excesses by the pharmaceutical industry. The 10 or so large firms of this industry support an enormous in house research and development effort. It is producing few new products (or insights) of significance. Meanwhile, fortunately, some 1400 biotech firms bubble with ideas.

Finally, US *universities* have expanded to the point where they depend on export of services and import of talent for survival. As is evident from Fig. 2, the population of universities has grown to fill the niche, and a daughter niche as well (consisting largely of branch campuses of state universities).[6] If other nations truly begin to compete in advanced research and graduate education, US universities may experience in the next 50 years some of the pains of competition that our steel and automotive industries have felt in the past 50 years.

The related pressures of cost, conjunctural change, and overcapacity properly cause Americans to examine the framework that supports Science International. Many questions must be explored, including the implications for individual disciplines, programmes, and projects; strategies for individual institutions; and restructuring of national scientific enterprises. The comments below will focus on a pair of paramount long term institutional needs. On the one hand, there is the need for organisations that can convene scientists from around the globe in their (non-governmental) capacity as individual experts and as professional groupings (usually disciplinary). On the other hand, there is the need for a mechanism to bring together the individuals within national governments who control the bulk of the resources for science.

Non-governmental infrastructure – ICSU

The point of departure for considering the international non-governmental structure in science is the International Council of Scientific Unions (ICSU), headquartered in Paris. Formally established in 1931, ICSU is an organisation of organisations. It includes 23 international scientific unions, which are largely disciplinary, and 92 national bodies, which are academies of sciences and like organisations. It also operates some 20 interdisciplinary bodies in fields such as water and ocean research.

The council shows promise of progressing to an effective mechanism for convening and networking the international scientific community. In principle, ICSU connects hundreds of thousands of scientists worldwide. In practice, few scientists know of ICSU itself, though many know particular adhering organisations.

At the same time, the familiarity with ICSU is growing among its principal partners, national governments and international organisations. The main reason is ICSU's contributions to the planning and conduct of global research programmes in the field of the environment.

The council must continue to demonstrate its utility. The best way is to expand its role in:

- assisting the formation of policies and plans for scientific research and education within the scientific community itself
- providing assessments and advice to governments and industry, that is scientific information for policy making.

A useful proposal is for ICSU to carry out a comprehensive, globally consistent study on human resource flows in science and engineering. Such a study, which seems never to have been performed, requires participation by the science and engineering communities in all countries, interests the professions themselves, and serves governments, industry, and intergovernmental organisations. If ICSU is to grow into a, or the, international counterpart of the US National Academy of Sciences as a pre-eminent technical advisory mechanism for government, it will be through testing itself on substantial questions of science and technology policy such as international flows of talent.[7]

Even as ICSU grows, particularly as ICSU grows, a serious evaluation of ICSU is needed. Its accomplishments in the environment have not been matched in other fields, for example genetics and high energy physics. (In genetics HUGO, an *ad hoc* organisation totally outside ICSU, was formed to help the international coordination of efforts to map the human genome; HUGO faltered badly.) The council also has weak links in engineering, medicine, and social sciences.

The electrification of Science International is also an important question for ICSU, which has the 'flat', network oriented structure preferred by many organisational theorists and corporations in the 1990s.[8] Making the flat organisation (or the virtual corporation) succeed globally requires investment in communication technologies and software and system design that the international scientific community is only beginning to consider.

The nature of the roles and commitment of the elected officers of ICSU, potentially key spokespersons for the international scientific community, must be revisited. The positions of President and Secretary-General of ICSU should probably become full time, compensated positions, and the other officers should probably become part time, compensated positions. The permanent secretariat of ICSU (some eight people) remains too small to meet internal needs as well as the growing demands from national governments, intergovernmental organisations, and industry for timely and sound expressions of the views of the international scientific community. Consideration must be given to enlarging the secretariat, but also perhaps to changing and decentralising it.

The ICSU must also mutually reinforce relationships with non-governmental scientific organisations that are, or can be, strong in geographic regions or other meaningful subsets of the world community. These include the Third World Academy of Sciences, African Academy of Sciences, International Institute for Applied Systems Analysis, and Academia Europaea and other non-governmental scientific organisations emerging on the European level. [Some alternative views on the status and development of ICSU are appended to this review.]

Science International must also be able to reach out to effective organisations concentrating the international talent in engineering and technology. The rapidly growing Council of Academies of Engineering and Technological Sciences, which assembles national academies of engineering and like organisations, shows great promise in this regard. More broadly, the bridges between international science and international industry need to be enhanced. Industrial organisations share concerns with the scientific community ranging from mathematics, science, and engineering education at all levels, through environmental quality, to orphan drugs (pharmaceutical products needed in developing countries where market demand may not support the cost of development and distribution).

The former Foreign Secretary of the US National Academy of Sciences, Walter Rosenblith, raised many of the issues here in a pair of ICSU conferences on 'International science and its partners' held at Ringberg, near Munich in 1985, and in Visegrad, Hungary in 1990.[9] Momentum for further analysis and action needs to be regained.

Now is the time to consider, comprehensively, the hierarchy, or perhaps network, of effective organisations, including national associations for the advancement of science, national academies of sciences, regional institutions, and global organisations that are ultimately required for effectiveness at the global level. There is an absence of any well drawn visions of the non-governmental side of Science International. The Carnegie Commission on Science, Technology, and Government made a few rough sketches, as has the US academy complex from time to time.[10] The US scientific community, singly and in cooperation with its counterparts, should try to depict some visions more fully and to identify the steps needed over the next 10–20 years to achieve them. The exercise will involve both abstract debate about models of consent, rationality, and decision making and haggling over specific issues, including membership, financing arrangements, and byelaws.

Intergovernmental infrastructure

The question of ICSU's twin on the intergovernmental side is the more difficult one. Leading figures for science in each national government can include a minister for science and technology, the president of a national science foundation or research council, and a science and technology adviser to the president or prime minister. There is at present no congenial and constructive context in which these individuals, representing at least the 20 or so leading scientific powers, regularly convene.

At least four possibilities to create such an organisation may be envisaged:

- make the 'S' in UNESCO work better. Over recent decades the leading governmental figures in science have rarely used UNESCO as the venue for their high level consultations. The reasons for this have been widely discussed

- take the 'S' out of UNESCO and form a new science organisation within the UN context. The success of the World Meteorological Organization and of the International Telecommunication Union demonstrates that it is possible to sustain a high quality, technically oriented institution within the UN system
- start a new intergovernmental organisation for science. Such an organisation could nucleate around the quasiperiodic meetings of heads of major national science foundations or science and technology advisers to heads of state. One of the promising consequences of the Carnegie Commission on Science, Technology, and Government has been the formation of the Carnegie Group of science advisers, including the science advisers of the G7 nations, Russia, and the top science and technology figure in the EU. This group does not include Sweden, Switzerland, The Netherlands, Israel, China, India, or Brazil, to name a few which are significant for Science International. China, India, and Brazil also do not belong to the OECD, which has established a Forum on Megascience, another possible entity around which to build
- form a 'bicameral ICSU' as proposed in the early 1980s by Robert M. White, President of the US National Academy of Engineering. In this model, ICSU would have a 'governmental council' of its own. The World Conservation Union (IUCN) is an example of an international organisation that has a governmental council as well as a non-governmental structure. The IUCN is predominantly a non-governmental organisation, but also has some 60 'state' members that pay dues. The dual character of IUCN has helped its ability to stimulate intergovernmental action and conventions in areas such as protection of endangered species.

Each of these options and others should be explored thoroughly.

In fact, the broad question of science in the UN system is badly overdue for examination. Science and technology have again come to the fore in the UN because of interest in sustainable development. The UN is not, however, carrying out its ongoing reorganisation with attention to science and technology *per se*. Nevertheless, consideration of the UN will probably not be fruitful except in a larger context embracing NATO, OECD, the EU, and other intergovernmental organisations important to science and all in turmoil.

Conclusion

Now is the right time to begin to set in place the infrastructure for Science International for the next 50 years, for the science of the 8000 million who will already inhabit the planet by 2020, and the thousands of millions more who will follow.[11] There is no alternative for problem solving to more and better science, and if nothing else, everyone needs to be prepared for the costs.

Science has lived until now with *ad hoc* arrangements for international dealings in each of its fields. The time has come to create better meeting places for all concerned – market places in a sense – in which potential participants in international scientific cooperation can gather, trade information, and, should they so choose, do business. There is no need to create bureaucracies to manage science internationally, but rather, as the volume of global transactions in science increases, frameworks that allow the community's affairs to be conducted reliably and efficiently.

To define the set of needed changes and build support for them, the international scientific community should explore, with government and industry, the creation of a major international commission to assess and make recommendations about the international infrastructure of science, both non-governmental and governmental, across all fields. Such a commission needs to be independent of ICSU and the UN system, in part because it must examine and address these bodies. It needs to reach out to young scientists to understand the emerging and unmet needs they experience.

A comprehensive, ambitious, long range review of the international infrastructure for Science International can succeed only if the US science and technology community and the US government provide strong support. My hope is that we will recognise that we have much to gain, as citizens of science and the USA.

Acknowledgements

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Comments and discussion

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Scientists feel part of a worldwide scientific community. They often find that they have more in common with scientific colleagues in other countries, however remote, than with many non-scientists in their own country. Traditionally, international scientific conferences have acted as 'international market places', while today email allows instant communication between scientists on opposite sides of the world.

Also, more and more scientific problems today are global (like climate change, in the study of which ICSU is playing a big part, and many forms of pollution) or include global aspects (biodiversity, marine biology). Some fields of science are too costly for any one country to support – space science, for example, or high energy physics, with its great international centre at CERN.

However, national science is important too. No one country can hope to excel across the board, and different countries have different areas of expertise. Population geneticists tell us that the most rapid evolutionary advance occurs when a species is split into small, semi-isolated populations with gene flow between them. Substitute 'information flow' for 'gene flow', and perhaps we have a recipe for rapid scientific advance?

If scientific diversity is desirable, then rather than creating more 'top down' international organisations, with their attendant bureaucracy, attention should surely be given to providing the means whereby less developed countries can build up their scientific infrastructure and scientific and technical expertise, using local talent and drawing on local culture and traditions. Do we really want science to function 'as one coherent, multinational entity' as Mr Ausubel suggests? Science should indeed be international, but we should beware of Science International Inc.

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Many of the points raised by Jesse Ausubel are being actively addressed by the International Council of Scientific Unions (ICSU), from perhaps a more international point of view, reflecting ICSU's global nature. The partnership between the communities of natural, social, medical, and engineering scientists is a reality and is being approached through numerous concrete joint activities dealing with such issues as population and resource use, land use, and natural disasters. The ICSU fully intends to pursue these with growing vigour in the years to come.

The other type of partnership which is important for international science is that with intergovernmental bodies, through which the independent scientific community of ICSU sponsors activities with UN bodies, thereby assuring that these have the support both of governments and of scientists. Examples of these concern the global observing systems for climate, oceans, and the terrestrial domain, and the programmes on climate research and biodiversity.

The ICSU has always been proud of its relatively small bureaucracy; indeed, its central secretariat in Paris has only eight paid members of staff, but there are other offices looking after ICSU's affairs throughout the world: the International Geosphere–Biosphere Programme office in Stockholm, the Committee on Science and Technology in Developing Countries office in Madras, the African Biosciences Network office in Dakkar, and the Committee on Biotechnology office in Moscow, to cite only a few. Thus, the administrative machinery, while still lighter than most other large international efforts, is not as small as Mr Ausubel's article claims. In addition, the most significant strength of ICSU, that of the thousands of scientists volunteering their time and effort to a common cause, should be given due credit. If this were translated into person-hours or dollars, both the human resource and the dollar budgets of ICSU would be formidable.