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The Third World Academy of Sciences

newsletter

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New Research Centres For Third World Proposed

In February 1988, Professor Abdus Salam, in his capacity as President of the Third World Academy of Sciences, conveyed to the Italian Foreign Minister, Mr. Andreotti, a proposal aimed at the establishment of three new international centres for research, at a high level of excellence, to be modelled on the lines of the experience gained during the 24 years of operation of the International Centre for Theoretical Physics (ICTP) as well as through the activities of the newly established International Centre for Genetic Engineering and Biotechnology (ICGEB), sponsored by UNIDO.

In the opinion of Prof. Salam, there is a great demand among the scientific community of the Third World for the experience so far obtained in physics, mathematics and molecular biology to be duplicated in a broader disciplinary scope, maintaining, at the same time, emphasis on an interdisciplinary approach so that scientific knowledge and science-based technology could have an additional, efficient channel for transfer, particularly toward the developmental efforts of Third World countries.

The Italian Government has welcomed the proposal as it falls in line with the new guidance for its technical assistance activities which now encompass scientific research and transfer of technology (including "high tech") among its priorities. The Italian Foreign Ministry has asked UNIDO to support the preparatory phase of the establishment, in Trieste, of the above new activities, in cooperation with the Third World Academy of Sciences, through a project which has so far been financed out of the Italian contribution to the Industrial Development Fund. Mr. Rosso Cicogna has been nominated as Project Leader for the International Centre for Science and High Technology, which will group three new institutes. Mr. Rosso Cicogna, a career diplomat, previously the Italian Representative to ICTP and the national coordinator for the setting up of ICGEB, will take care of relations with the Italian Government and other institutions of the UN family, some of whom have already expressed interest in joining the initiative.

Nobel laureates Prof. K. von Klitzing (standing right), Prof. K.A. Mueller (left), Prof. Abdus Salam (centre), Prof. K. Siegbahn (right) and UNIDO Project leader Mr. G. Rosso-Cicogna (standing left) recently met to examine the proposal for the establishment of the International Centre for Science.

The activities of the International Centre for Science and High Technology in fact began in July last year and included brainstorming sessions and informal consultations. Two more formal meetings have now been organized for each of the three new Centres involving top scientists and technologists from Italy and all over the world but mainly from developing countries. The network of TWAS members has made an invaluable contribution in this regard. Charged initially with the responsibility of conducting the Centre's feasibility, the

TWAS has successfully completed the preliminary exercises. Currently, the Academy is locating prospective Third World scientists from its vast membership network who could play a role in the operation of the Centre. The initiative of Prof. Salam has thus received a response beyond original expectation.

As a result of this preliminary work, the initial main lines of research have been identified.

For the Centre for Earth Sciences and the Environment, priority will be given to earthquake and mineral deposit prediction, air-sea-land interaction in view of climatic changes, upper-middle-lower atmosphere interactions with special emphasis on the tropical ionosphere, and environmental control and remote sensing. With regard to the Centre for High Technology and Advanced Materials, the initial activities will concentrate on micro-processors, photonics (optical fibres and lasers), high-temperature superconductors, semiconductors and composites. The Centre for Pure and Applied Chemistry's initial research will focus on polymers, catalysis and reactivity, fields attracting particular attention in view of their relevance to industrial application.

Common feature

A common feature of the three new Centres will be the duplication of modalities so far pursued with the ICTP which, though successful, will have to be adapted to experimental disciplines. Emphasis will be placed on training as well as on specific research projects in which scientists and technologists from Third World countries will be involved for different periods of time, with a view to their returning home to re-import the scientific knowledge and "know-how" acquired in order to start similar activities in their institutions of origin, while maintaining a steady link with Trieste. This modality is meant to act as an efficient anti-brain-drain device.

A second common feature of the three new Centres will be the availability in Trieste of joint experimental facilities with advanced instrumentation which would not be found today, or in the near future, in laboratories in developing countries because of the exorbitant costs and excessive sophistication, and also in view of maintenance and/or the fact that these facilities would simply not be justifiable in view of the limited community of users which could be served in this manner. Such facilities would instead be at the disposal, in Trieste, of scientists from all over the world for their experiments, working together with permanent research groups at the Centres in tune with the philosophy similar to that which is commonly known in all large physics facilities catering for users from many external laboratories.

A third common feature would be the availability, in Trieste, of a joint computer facility, to be used also for the purpose of training operators of computer centres in developing countries and ready to assist in the up-grading and optimal use of hardware existing in the latter.

An interim report for each Centre was reviewed in December last by a panel of top-level experts, membership of which included several Nobel Laureates. The reports provide a solid base for the establishment of the International Centre for Science and High Technology. They also identify pilot activities (worth 10 million dollars for the next two years), which will commence this year, initially hosted at the premises of ICTP, and which will help in the definition of the final programmes of the three Centres once the International Centre for Science and High Technology (comprising the three Centres and eventually aggregating the ICTP and ICGEB) has been formally launched. For the initial phase of its steady state operation after 1990, it is expected that the three Centres will be funded with 10 million dollars a year each. ■

TWAS Support to Third World Scientists in 1988

During 1988, the Third World Academy of Sciences extended financial support to developing country scientists totalling US$ 820,000.

TWAS Research Grants

The Academy awarded 144 Research Grants worth US$558,471 to scientists from 46 Third World countries. The grants would support research in the important fields of Experimental Physics, Pure and Applied Mathematics, Biochemistry and Molecular Biology (Table 1). As of 1989, the programme has been expanded to include Pure and Applied Chemistry.

As Latin America and Asia continued to be the major recipients of TWAS Grants, Arab and African scientists made a significant headway in benefitting from the Academy's assistance: the Arab countries' share of TWAS Grants went up from 5.49% in 1986/87 to 10.42% in 1988. The African countries' share also went up in 1988 with a gain of 3.87% over that of 1986/87.

(A list of the grant recipients and their research project titles is being published in a brochure and will be available from the Office of the Executive Secretary.)

South-South Fellowships

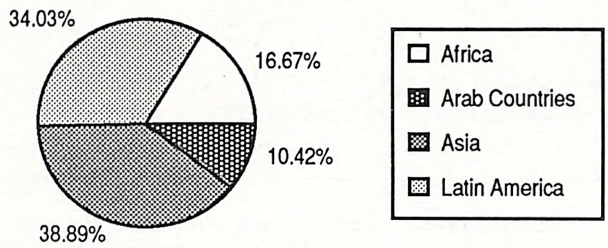
During 1988, the Academy supported 40 scientists from 23 Third World countries to visit institutes in 13 developing countries. An amount of over US$ 51,000 was spent on travel to and from the host institutions' countries (Table 2).

Most of the scientists (55%) who were awarded a South-South Fellowship travelled to Latin America as a relatively large number of organizations which have agreed to cover local expenses for visitors to their institutions under this programme are located in Latin America. To be precise, of the 257 fellowships offered yearly by 15 countries in the Third World, 120 have been offered by Latin America alone.

Table 1: TWAS Research Grants Awarded in 1988
Distribution by field and country

	Country	*Pure & Applied Mathematics*	*Experimental Physics*	*Molecular Biology/ Biochemistry*	*Total by Country*
1	Argentina		2	8	10
2	Bangladesh			1	1
3	Benin			1	1
4	Bolivia		1		1
5	Botswana		1		1
6	Brazil		2	4	6
7	Chile	1	1	6	8
8	China, P.R.	1	8	4	13
9	Colombia			1	1
10	Congo			1	1
11	Cote d'Ivoire		2		2
12	Costa Rica			2	2
13	Cuba	1	2		3
14	Egypt		2		2
15	Ethiopia			2	2
16	India	2	6	1	9
17	Iran	1	1		2
18	Iraq			1	1
19	Jamaica		1		1
20	Jordan		2	1	3
21	Kenya		1	1	2
22	Korea			1	1
23	Lebanon			1	1
24	Madagascar		1		1
25	Malaysia		2	1	3
26	Mexico		4	6	10
27	Morocco		1	2	3
28	Nepal			1	1
29	Nigeria	2	2	7	11
30	Pakistan		6	6	12
31	Panama			1	1
32	Peru			1	1
33	Philippines		1	1	2
34	Rwanda		1		1
35	Sri Lanka		1	3	4
36	Sudan	1	2		3
37	Syria			1	1
38	Tanzania		1		1
39	Thailand		2		2
40	Trinidad			1	1
41	Turkey		3	1	4
42	Uruguay			1	1
43	Venezuela			3	3
44	Vietnam		2		2
45	Yemen Arab Rep.		1		1
46	Zimbabwe			1	1
	Total by Field	*9*	*62*	*73*	*144*

Research Grants Awarded in 1988: Distribution by Region (All fields)



(A brochure containing the list of all the recipients and addresses of the host institutions can be obtained from the Office of the Executive Secretary.)

Scientific Meetings held in Developing Countries

The purpose of the programme is to encourage the organization of regional and international scientific conferences, workshops and special meetings in the Third World.

87 activities held in 37 developing countries were financially supported by the Academy in 1988 (Table 3). A total of US$ 211,687 was spent on travel support for principal speakers and/or young scientists from the region where the meeting was held.

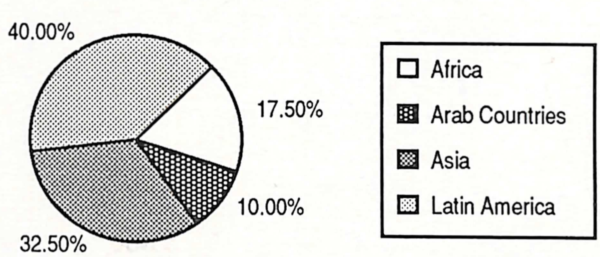
The breakdown by region shows that the TWAS recipients most active in promoting scientific contacts through meetings, workshops, seminars and conferences last year were the Latin Americans: 40.45% of TWAS contributions under this programme went to the South American continent.

(A list of meetings sponsored by TWAS is available from the Office of the Executive Secretary in the form of a brochure.)

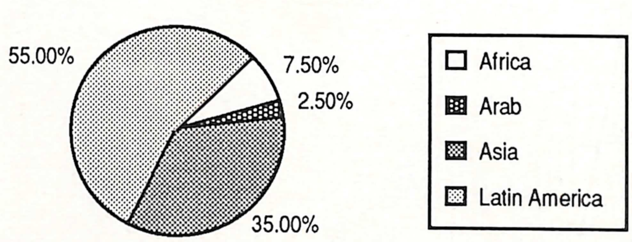
TWAS Italian Awards for Research and Training in Italian Laboratories

Another major programme which the Academy has drawn up for scientists in developing countries allows them to visit Italian laboratories and work in the fields of biology, chemistry and geology. The average duration of these fellowships varies from 10 to 12 months.

Fellowships Awarded in 1988: Distribution by Region



Host Institutions in 1988: Distribution by Region



Since the inception of the programme, over 80 scientists from the Third World have come to Italy to spend time in one of the 120 Italian institutions participating in the Scheme.

The success of this initiative has been very encouraging. The Italian government has generously offered US$ 1.6 million as a contribution to increase the number of Third World scientists taking part in this special fellowship programme.

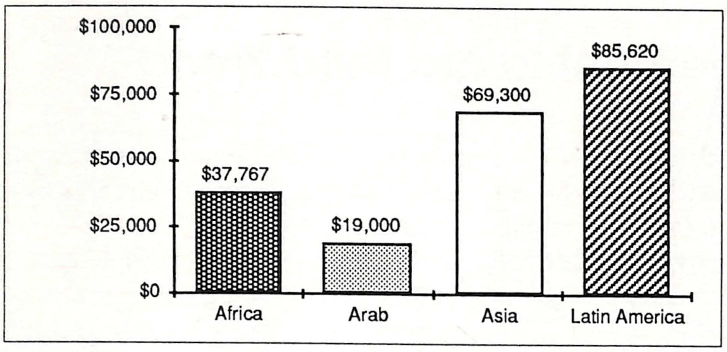
Table 2: South-South Fellowships Awarded/Hosted in 1988: Distribution by country

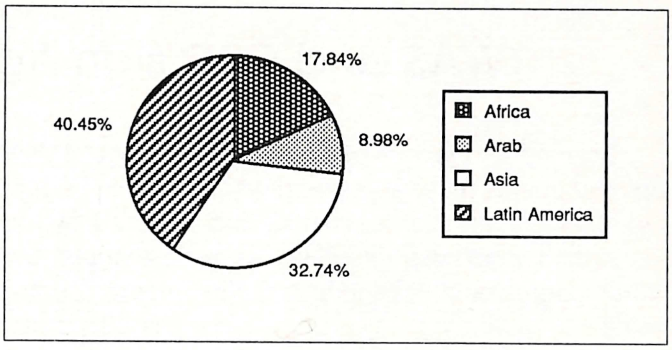
Country	*Fellowships Awarded*	*Fellowships Hosted*
Argentina	2	2
Bangladesh	1	
Benin	1	
Brazil	4	7
Chile	2	5
China	4	2
Colombia	3	
Cuba	1	
Egypt	2	1
Ghana		1
Guinea	1	
India	3	8
Kenya	1	1
Korea, South	1	
Malaysia		3
Mexico		6
Nepal	1	
Nigeria	3	
Pakistan		1
Peru	1	2
Sri Lanka	1	
Sudan	2	
Tanzania		1
Thailand	1	
Uganda	1	
Uruguay	2	
Venezuela	1	
Vietnam	1	
Total	*40*	*40*

The Italian Research Council has also expressed its interest in the scheme. Several of the institutions receiving visitors under this programme are in fact affiliated to the *Consiglio Nazionale delle Ricerche (CNR)*,which has offered the Academy a contribution of US$ 75,000 for this activity.

A brochure listing all institutions participating in the scheme with their respective areas of research can be requested from the Office of the Executive Secretary.

It is expected that more and more Third World scientists will benefit from this opportunity of exchanging and sharing scientific know-how in areas where Italian expertise is universally recognized. ■





Regional distribution of funds for promoting scientific activities in developing countries

Table 3. TWAS 1988 Grants for scientific meetings in developing countries

Country	*Biological Sciences*	*Chemical Sciences*	*Geological Sciences*	*Interdisciplinary Sciences*	*Total Amount Granted (US$)*	*Total*
Argentina	5	6			23,990	11
Bangladesh		1			4,200	1
Benin	1				3,000	1
Brazil	2	1	1		19,000	4
Chile	4	1	2		12,890	7
China	6		3	1	19,100	10
Colombia	1				2,500	1
Cuba	2				2,850	2
Ecuador	1				5,000	1
Egypt	1		2		6,000	3
Ethiopia		1			2,000	1
Fiji		1			2,000	1
Gabon	1				1,500	1
Ghana	2				5,000	2
Guinea	1				767	1
Honduras				1	3,000	1
India	2	1		1	7,000	4
Jordan	2				4,000	2
Kenya		1			3,000	1
Madagascar	1				1,000	1
Malaysia	1	1	1	1	16,500	4
Mexico	1	1			6,000	2
Morocco			1		5,000	1
Nigeria	2				6,000	2
Pakistan	1	1		1	9,000	3
Philippines	2				5,000	2
Senegal	2				9,000	2
Sierra Leone	1				2,000	1
Singapore		1			2,000	1
Sudan	2				5,000	2
Syria				1	3,000	1
Thailand	3	2			9,350	5
Trinidad	1			1	6,000	2
Turkey	1				2,000	1
Uruguay	1				1,500	1
Venezuela	2				2,890	2
Zimbabwe	2				4,500	2
Total 37	*54*	*19*	*10*	*7*	*212,537*	*90*

TWAS and CSC sign Agreement to aid Third World

Science and technology in developing countries received a boost when two leading international scientific bodies signed what was described as a historic agreement in Nigeria last November.

The Third World Academy of Sciences and the Commonwealth Science Council (CSC) reached the agreement during the 15th two-yearly meeting of the CSC in Lagos, the Nigerian capital.

They pledged to work together to "further the development of science and technology in the Third World as well as their proper applications in relation to the requirements of society."

They agreed to develop programmes of common interest to promote research by Third World scientists and scientific institutions and facilitate their contacts with the global scientific community.

The CSC and the Academy will exchange scientific information of mutual interest on a regular basis. This will include books and periodicals, newsletters and reports.

They will also disseminate information on each other's programmes and activities to scientists of Third World origin working in scientific institutions in the developing world and elsewhere.

The agreement was signed by the outgoing chairman of the CSC, Professor Ephraim Okon of Nigeria, and Professor Mohamed Hassan of Sudan, Executive Secretary of the Academy, representing Professor Abdus Salam, the President.

Professor Okon, 48, who was succeeded as CSC Chairman by Professor Peter Serracino-Inglott of Malta, described the agreement as "a historic endeavour."

He said: "The CSC believes in seeking and fostering collaboration with scientific bodies of international repute. Science thrives by research, exploration, debate, inter-action and a free exchange of views and information."

The signing ceremony was witnessed by top scientists and science managers from some 40 Commonwealth countries who were in Lagos for the CSC biennial.

Among them were the CSC's immediate past chairman Dr. Jim Ellis, Director-General of New Zealand's Department of Scientific and Industrial Research, who hosted the 14th CSC biennial in Wellington in 1986.

The London-based CSC is the main inter-governmental agency for promoting scientific cooperation in the Commonwealth. All but four of its 34 members are developing nations. (The four developed countries are Australia, Britain, Canada and New Zealand).

Professor Hassan expressed the Academy's pleasure in forging links with the CSC. "We are extremely delighted at this agreement," he said. "CSC programmes are relevant to our work and, we hope, our activities will be of interest to the CSC.We are definitely going to run programmes jointly with it."

Professor Hassan, 41, formerly Dean of the School of Mathematical Sciences of the University of Khartoum, was in Lagos for most of the CSC's week-long meeting and was thus able to gain a good idea of its work.

"From what I've seen here in the last few days, the CSC is doing quite a lot in scientific and technological cooperation in the Commonwealth, both developed and developing nations."

He witnessed the launch of a new CSC programme called Awareness of Rapid Advances in Science and Technology (ARAST) which aims to help young scientists and teachers from Commonwealth developing countries keep abreast of advances in areas such as biotechnology, microelectronics, materials science and technology and design engineering.

As part of this new initiative the CSC will hold a pan-Commonwealth workshop in Pune (formerly Poona) in India in January 1989.

Professor Hassan called ARAST "a very important programme" and offered travel grants from the Academy to enable young scientists to attend the CSC workshop. So the first tangible result from the agreement came before the ink on it was dry.

He said non-Commonwealth academy members would benefit from CSC programmes. These span seven broad areas: energy resources, biological resources, environmental planning, agriculture, industrial support, water and mineral resources and science management and organization.

"I'm amazed at the range of CSC programmes considering its small staff and budget," said Professor Hassan. "It's a very successful story. I'm surprised this Agreement did not take place sooner as it would have been in the interest of both of us."

He invited the CSC to join an Academy programme to encourage women to take up leadership roles in science and technology. The programme, supported by the Canadian International Development Agency, was launched in October when women scientists from 80 countries met in Trieste.

The CSC itself has been actively promoting the involvement of women scientists in its work. Its secretary, Dr. Gopalakrishna Thyagarajan of India, told the Lagos meeting that more than half of its professional staff were women and that about a quarter of all Commonwealth scientists who took part in its activities last year were women.

Responding to a question from Mrs. Sonia Saumier-Finch of Canada, he assured the meeting of the CSC's continued efforts to involve more women scientists in its future programmes. ■ Asif Khan

IRPA* as a Strategy for S&T Development in Malaysia

Capital, labour and technological change are interrelated factors in economic growth. Capital investment, for example, can serve as a catalyst to trigger off a self-sustaining virtuous cycle of technological change eventually resulting in productivity or quality improvement in goods and services.

Technological change can be purchased or can arise from R&D. In developing countries, not enough attention has been paid to the role of capital investment in stimulating technological change through R&D. This reflected in a generally low R&D spending of less than 0.2% of the GNP compared to the order of 2-2.5% in developed countries.

However, the science and technology which support technological change are in a state of flux. Because of the rapid advances in precision instrumentation, and in electronic information gathering and processing systems, and because of increasing interdisciplinary collaboration, new scientific fields are being created as traditional ones merge or are redefined. This has happened with molecular biology, materials science, photochemistry and microelectronics, to mention a few. Boundaries between basic and applied research are eroding and in many fields the time between discovery and its commercialization is now a matter of years rather than decades.

The possible range of S&T areas that might be pursued is getting wider so much so that even the most developed countries are not in a position to pursue all the areas. They are forced to make choices and set priorities.

The case for targeted development in S&T

"Corporate Planning" for S&T with selection of priority is a much discussed topic in both the developed and developing world. Even in the USA (Ref. 1) a proposal has been made recently to categorize S&T activities into three groups of descending priorities as follows:

Category 1: (a) Preserving the human resource base and the pipeline for S&T. This means absolute priority for training and research grants reaching the largest number of scientists, engineers and clinical researchers; (b) Meeting the S&T requirements to deal with national crises (giving R&R for AIDS as an example); (c) Pursuing extraordinary scientific breakthroughs (e.g. High temperature superconductivity).

Category 2: Pursuing large projects with important national or scientific goals.

Category 3: Pursuing projects associated with political or national prestige objectives.

The proposal entails priority determination across scientific fields with strong coordination and a "rationale for a coherent and adequate national S&T budget".

South Korea, a newly industrial country, has set an ambitious national goal of joining the OECD countries in the 21st century. Its *Long-Range Plan for S&T Development Towards the 2000's* (Ref. 2) categorizes R&D activities into five priority areas:

Group I includes areas whose economic returns may be expected in the near future — e.g. informatics, fine chemistry and precision machinery. For this priority group, the goal is to reach the level of the most advanced nations by the year 2000.

Group II encompasses areas with strong possibilities for medium-term success — e.g. biotechnology and new materials. The goal for this group is to approach the level of the advanced countries by the year 2000.

Group III covers areas related to public welfare, environment and health. The goal is to reach the present level of the advanced countries by the year 2000.

Group IV consists of technologies with future prospects, e.g. oceanography, aeronautics and space technology. The R&D activities in these fields will be confined to follow-up work to catch up with the advanced countries by the year 2000.

Group V includes basic sciences and engineering which provide common bases for areas of Groups I-IV. The goal is to approach the level of the developed countries by the year 2000.

The strategies for implementation are to invest intensively in targeted areas and to encourage cooperative research both nationally and internationally.

Support for any area of S&T does not now come automatically in the UK. The Advisory Council for Applied Research and Development (ACARD) (Ref. 3) has had to make a case for *strategic science* by citing it as an investment decision in which current outlays are incurred in anticipation of future returns. The objective is to create a portfolio of areas of S&T on which the country's industry would draw over an extended period so as to ensure its future competitiveness in international markets.

ACARD proposed that the elements of a strategy for making suitable S&T investment decision are: (a) criteria for choice, (b) the identification and collection of relevant information, and (c) an institutional mechanism which ensures that the country's industry does indeed draw successfully on the strategic sciences and related enabling technologies.

ACARD concludes that it is both feasible and desirable to create a framework for an agreed process for generating priorities in strategic exploitable areas of science. Such an activity cannot be carried out occasionally, but must be continuous with sufficient resources committed, both in quantity and time, to ensure consistency of judgement.

The UK Advisory Board of the Research Council (ABRC) (Ref. 4), on the other hand, advocates maintenance of active research capacity across a wide range of basic sciences, on the basis that few scientific fields are sufficiently

* Intensification of Research in Priority Areas

For the developing countries, where resources are always limited, strategic planning for growth in targeted areas is the only option open.

freestanding to develop in isolation. Justification is made on purely scientific considerations without any regard to strategic potential. However, prioritization still comes into consideration and the following criteria are proposed as a check-list in priority determination:

Internal — Timeliness, pervasiveness and excellence.

External — Exploitability, applicability, and significance for education and training.

In the light of the two reports, the new UK Advisory Council for S&T (ACOST) was set up in 1987, and has been asked to advise the Government (Ref. 5) on priorities for key areas of emerging S&T relevance to the following: (i) advanced materials; (ii) biotechnology and life sciences; (iii) communication and control; (iv) design and manufacturing.

The key aspects to be highlighted in relation to each area are the following: (a) Does it have wide applicability, both for improving the quality of life and for commercial exploitation and what are likely to be the main market opportunities? (b) What are the relative strengths and weaknesses of the UK with respect to underlying science, advanced industrial capacity? (c) Whether and if so, how the UK should seek to put itself in a strong competitive position?

It is clear therefore that judgement of affordability and relevance comes into major consideration in planning for S&T development. *For the developing countries, where resources are always limited, strategic planning for growth in targeted areas is the only option open.* Intensification for Research in Priority Areas (IRPA) is being developed in Malaysia to meet this objective.

Strategies for S&T development in Malaysia

A National Science and Technology Policy (NSTP) (Ref. 6) was formulated and approved by the Government in 1986. Its policy statement proclaims that the NSTP, being part of the socio-economic development policy of the nation, "(a) is to promote the utilization of S&T as a tool for economic development, the improvement of human physical and spiritual well-being and for the protection of national sovereignty, and (b) shall focus on the promotion of scientific and technological self-reliance in support of economic activities through the upgrading of R&D capabilities by the creation of an environment of scientific, educational and other relevant infrastructures."

Consequently, in national development planning, for the 1986-1990 period (the Fifth Malaysia Plan - FMP) basic issues in S&T received attention, particularly in the direction and guidelines for support for R&D as a means of "generating better efficiency, improved productivity and increased competitiveness not only in the agricultural sector, but also in all other sectors of the economy particularly manufacturing." In Chapter VIII of the FMP 6 document (Ref. 7) the issues are dealt with under the following headings:

(a) *Management of Science & Technology* — strengthening the S&T management system to enable a more centralized planning and coordinated implementation of R&D to meet national objectives and priorities; the training of research leaders development of S&T indicators;

(b) *Resources Allocation for Research and Development* — increasing the allocation to S&T and the creation of an R&D development vote;

(c) *Categories of Research and Development* — providing a guideline to ensure an adequate and balanced approach to basic, applied and developmental research;

(d) *Private Sector Involvement in Research and Development* — encouraging, through tax and other incentives, more R&D activities by the private sector;

(e) *Scientific and Technical Manpower* — providing a manpower planning mechanism which is properly linked to the training institutions and the user agencies, both in the public and private sectors;

(f) *Research and Development Priorities* — calling for identification of priorities for increased productivity and diversification of the industrial base;

(g) *High Technology and Strategic Activities* — identifying enabling technologies in support of industrialization and other areas of national concern;

(h) *Transfer of Technology* — considering the mechanism for technology acquisition, diffusion and generation;

(i) *Popularization of Science* — providing the means of general exposure to S&T and the mobilization of scientific manpower for the advancement of S&T and the establishment of a National Academy of Science.

The IRPA Strategy

Intensification of Research in Priority Areas (IRPA) was originally formulated as a procedure in budgetary resource allocation to R&D to provide greater accountability and sensitivity to national development needs (Ref. 8). Its implementation involves R&D priority determination at national and institutional levels and the formulation of research proposals based on these priorities as well as peer group appraisal and built-in monitoring and evaluation. IRPA is therefore not just a procedure but a strategy of S&T development. Indeed, the implementation of IRPA satisfies several strategies of the FMP simultaneously and constitutes the first steps in targeted S&T development planning.

Priority Determination

In determining R&D priorities at the national level, the following points are taken into consideration: (a) Government policy statements and objectives; (b) need enunciations form users (e.g. industry); (c) current status of resources and constraints; (d) research needs arising from challenges of policy decisions or user needs.

Government policies which become major reference points for priority determination include the New Economic Policy, the National Agricultural Policy, the National Science and Technology Policy, the Industrial Master Plan, and the FMP document itself.

At the institutional level, priority determination is based on the national priority listings taking into account institutional mission and/or special strengths. These are then translated into institutional R&D trust areas and finally project proposals.

For the purpose of IRPA, R&D priorities are categorized into agricultural, industrial, health and strategic. Activities related to economic development are covered under agricultural and industrial research. Health and strategic research includes activities that ensure human health and welfare, monitor national resources, support national security, and enhance R&D productivity. Strategic research also covers the basic sciences, particularly those in the realm of the so-called exploitable areas of science.

R&D Assessment

IRPA calls for two levels of appraisal of the research proposal. The first level is institutional where technical merits and economic viability are looked at. This in-house ex-ante evaluation is carried according to standard procedure for the institution concerned. Some institutions operate through technical advisory boards or research councils. The universities normally screen proposals through faculty research committees and/or university research committees.

Supported programme proposals are then submitted to the National Council for Scientific Research and Development (NCSRD) where a second level appraisal is carried out by "IRPA Panels", one for each category of research.

The IRPA Panels appraise programmes for relevance to national priorities, technical and/or socio-economic benefits, cost effectiveness, interdisciplinarity, intra- and inter-institutional collaboration and involvement of industry. IRPA Panels are formed of Senior R&D managers (Directors General of Research Institutions, Vice-Chancellors) and representatives of industry.

Supported proposals are then forwarded to the Economic Planning Unit and the Federal Treasury for funding. Approved funds are disbursed by the Treasury to the research agencies through usual channels.

In summary, the four key stages of prioritization leading to the submission of an R&D portfolio in support of an R&D budget allocation are as follows: (i) articulation of research needs related to sectoral priorities and user needs (e.g. private industry), carried out at the NCSRD level (these are indicative areas for R&D support in each area); (ii) identification of research possibilities based on research resources available (manpower and scientific instrumentation), costs, timeliness and quality, carried out at the institutional level; (iii) process of matching R&D possibilities with research needs, carried out by IRPA Panels; (iv) prioritization of research possibilities and selection of those to be integrated into a portfolio for submission to the Federal Treasury and the Economic Planning Unit in support of an R&D budget application, carried out by the IRPA Panels.

Appraisal, monitoring and ex-post evaluation activities are built in from the outset into the research process at the institutional level and into the overall budgetary process at the national level, thus being part of the integrated process, rather than separated activities.

Benefits of IRPA

The FMP provided for an R&D Development Vote of $400 mil for all public sector research for the 1986-1990 time frame. This is a substantial increase, pushing national R&D expenditure from around 0.5% of GNP in the previous years to almost 1% during the FMP period (Ref. 9). IRPA is devised to manage this R&D fund with accountability and with an improved chance of deriving full benefit from the research effort.

Despite a fairly centralized pattern of management in national development planning in Malaysia, R&D management had been pluralistic. The FMP document states that "there was... an absence of overall direction and comprehensive and explicit strategies and policies on S&T resulting in research institutions continuing to establish their own objectives and priorities." The national R&D effort was, in other words, undertaken without focus and serious attempt at coordination. IRPA has changed that. There is now both focus and coordination. Wasteful duplication can be reduced and interdisciplinarity as well as collaborative effort can be encouraged.

A guideline in research allocation to basic, applied and development research was drawn up in the FMP to ensure that an appropriate balance is maintained (see Table below). The FMP has also defined the role for the universities in the national R&D effort, namely that they should carry out most of the basic research especially in areas supporting the applied and development research of the research institutions, and in the exploitable areas of science. Through IRPA, both the balance in the three categories of research and the role of university research can be monitored.

The government's and the researcher's perspectives on R&D sel-

Distribution of Resource Allocation to Types of R&D by Categories

Research Institutions	*Types of Research*			*Distribution (%)*
	Basic	*Applied*	*Developmental*	
Universities	40	50	10	22
Government R&D Institutions	10	35	55	52
Private Sector R&D	5	20	75	26
Total Allocation (%)	18	35	47	100

(From the Fifth Malaysia Plan, 1986-1990) dom coincide. The choice between the *search for truth* and the *demand for utility* as a major reason for research is a continuous tussle. Through the effort in priority determination, areas of concern to the government are brought to the attention of the researchers. Conversely, matters of concern to the researchers are explained in an integrated and holistic manner by the IRPA Panels to the central science agencies in their recommendations. Thus a common platform for a meeting of minds is being forged.

The fact that IRPA calls for appraisal of research proposals by peer groups (IRPA Panels) and for continuous monitoring and evaluation will encourage better choice, preparation and presentation of research proposals followed by better conduct of research. In the long run, this will improve the quality of research and that of S&T in the country generally.

In the context of IRPA, Quality of R&D is best regarded as not only related to the intrinsic properties of the R&D, but also related to the needs at which it is targeted (extrinsic properties). Intrinsic properties are broadly those associated with the R&D proposal itself, having the following aspects:

(i) Is the proposal breaking new scientific ground?

(ii) Could the objective of the proposal be achieved by methods not involving R&D or involving less R&D?

(iii) Has the proposal been formulated and structured in a manner that its objectives are likely to be met within the allocated resource cost and time?

(iv) Has it been formulated in a manner which readily permits assessment and monitoring?

All of the above can be evaluated at the institutional level, although special arrangements may need to be made for interdisciplinary issues.

Extrinsic properties which need to be evaluated outside the institution should have a balanced research portfolio in the light of its overall objectives. This is in the interests of maintaining a high quality and flexible output from the institution over time. At the NCSRD level, the overall quality requirement is that, taking into account national needs and international S&T developments, the country overall has an adequate spread of S&T skills and R&D activities in progress within the constraints of national resource limitations.

In the information provided to, and assessed by IRPA Panels, there is material enabling all of these quality factors to be considered.

The future of IRPA

IRPA is in the second year (1988) of operation and work for the third year will soon start as part of FMP. The process of priority determination and appraisal of R&D proposals is not perfect. Experience from around the world indicates that any R&D priority setting is liable to be a messy business and continuous improvement and adaptation is a necessity.

This Workshop is a manifestation of a conscious and pragmatic effort to improve progressively. The criteria for priority selection and the indicators for priority setting are some of the parameters that need improvement, particularly in relation to the next Sixth Malaysia Plan. To achieve this, NCSRD will need to perform a number of analyses, such as (a) analyses of available and required professionals and scientific instrumentation in relation to IRPA priorities; (b) identification of user (e.g. private sector) needs for consideration in priority setting; (c) identification of scientific research priorities at the inter-institutional level with the purpose of identifying needs for strategic research; (d) analyses of funding from international organizations and private sector for R&D in relation to IRPA priorities; (e) initiation of an annual review of R&D budget allocations (including identification of indicators in relation to IRPA priorities); (f) analyses of the strengths, weaknesses and opportunities for Malaysian R&D in the region and in the world.

The activities in priority setting currently practised stop short of spelling out the nature of R&D that needs to be done. This results in a kind of supply-push situation where the R&D agencies are left with the onus to propose the actual research to be done. There are many drawbacks to this. A better approach is perhaps a combination of the above and a demand-pull situation where research needs are spelt out and institutions are invited to bid; the one best suited for the task from the viewpoint of technical expertise and/or readiness to collaborate wins the project.

The involvement of wider cross-section of the scientific community in R&D planning and management may be desirable especially in determining priorities in the exploitable areas of science. Here learned societies may be involved to provide the feedback to the NSCRD. These societies may, for example, provide the following information: (i) latest global development in an exploitable area of science; (ii) implications for industry; (iii) relevance to Malaysia; (iv) suggestions for action with respect to policy decision, organizational and infrastructural changes, manpower development, R&D activities and international cooperation.

With IRPA, a means is now available to plan and plot meaningful R&D activities. The continuing support from the central agencies is, however, crucial to the success of IRPA strategy.

The complexity of IRPA is evident. Its many interfaces with government agencies present potential areas of conflict. Viewed positively, however, the multiple relationships can bring forth cooperation and support to strengthen a common national objective.

Conclusion

During the current FMP, Malaysia has moved firmly towards the direction of a centralized and coordinated system of R&D management in line with its overall national development planning process. IRPA is a means of achieving that objective. However, because of its far reaching implications, IRPA, through upgrading of research in exploitable areas of science and applied research in sectoral areas for economic growth, is in reality a strategic planning mechanism for S&T development in targeted areas. With improvement of its various procedures and continued support form both the research community and the government, IRPA will raise the status of S&T in Malaysia and enhance the contribution of S&T to economic growth.

The Malaysian endeavour through IRPA to adopt a systematic approach to R&D budget justification and allocation is perhaps unique among the less advanced countries. It may be a model for other countries to follow making those adaptations necessary to suit geographical, historical, social and cultural uniqueness in each nation.

■ Omar Abdul Rahman and Michaela Y. Smith (Paper delivered at Seminar on Strategic R&D Planning and Management: Priority Setting and Quality of R&D, Kuala Lumpur, 8-11 August 1988, organized by Malaysian Government and Commonwealth Science Council).

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Science Journals: A Third World Perspective

The under-representation of Third World research in international science journals is a neglected aspect of science communication. According to Garfield, "Western journals control the flow of international science communication almost as much as Western news 'monopolize' international news. This is not a judgement but simply a statement of fact."

Because of a serious lack of bibliographical control and unorganized distribution systems, much original Third World research is not widely known. Most scientists in the West are not aware of research being carried out in the developing countries and libraries, institutions, etc. have difficulty in obtaining information on new Third World journals or even data on how to obtain the existing ones. Even scientists working in developing countries find it almost impossible to gain access to information on research on common problems and areas of common interest from other developing and regional countries. This is a serious constraint to the development of science.

Most prestigious, high-impact 'core' journals inadequately cover work conducted in the Third World as opposed to the 'non-core' journals that are published in the developing countries. Because of poor marketing and distribution, journals published in developing countries scarcely reach the readers in Western countries. Hence such journals are rarely cited in core journals.

According to international categorization, 133 countries are classified as developing and out of them the *Science Citation Index (SCI)* of the Institute for Scientific Information (ISI) covers journals from 15 countries only. No journal from the developing countries is ever placed among the top 1000 of the ISI journals. This reflects the lamentable lack of impact of the journals from the Third World. Out of the 2,540 source journals covered by the SCI, only 67 are from the developing countries. Even journals that publish Third World articles are ranked according to impact; no Third World journal appears among the top 25. When we consider the journals with the highest impact for Third World articles, the US journals account for two-thirds, followed by those published in the UK.

National Science Journals

Many developing countries publish an impressive list of journals, some decades old. Even smaller Third World countries publish a considerable number in comparison to the size of their scientific communities. Often the problem is not the quantity of such journals but their quality. Journals with a small authorship tend to have lower standards while those with a limited circulation are expensive.

The publication of local journals has been identified as an indispensable element in the development of national science infrastructures. A national journal reflects the quality of scientific work in a country even when some of the best papers are sent abroad. The existence of such a journal, besides proving an outlet for the publications of local scientists, enables to emphasie unique national aspects in specific areas of science.

Local scientists are often reluctant to publish their 'good' papers in national journals because they suspect that the journals are not well known and lack the desired standards. National journals also tend to cover a broad spectrum of topics — one of the reasons for their non-inclusion in information services and databases which tend to cover specialized areas of science.

At present, very little data and statistics are available on the present level and status of scientific journal publishing in Third World countries. In order to obtain accurate data and statistics and to identify the problems and constraints of scientific journal publishing in Sri Lanka, the Natural Resources, Energy & Science Authority (NARESA) carried out a national survey.

The findings of the survey revealed that the major problems in the editing of scientific journals were: (1) lack of training facilities for science editors; (2) the lack of printing facilities. Several of the printing units lack even the basic mathematical signs, an essential requisite for research journals. The relatively high-quality printers are overloaded with work and cause considerable delays in printing; (3) financial constraints; (4) lack of adherence to international standards; (5) poor circulation, and (6) problems encountered in selecting suitable referees.

I have therefore set out a number of recommendations for upgrading standards of scientific research journals in Third World countries, based on the issues and constraints identified by the survey.

- Developing countries should concentrate on publishing a few journals of good physical and editorial standards which carry papers of merit, rather than diffuse the limited funds available into many journals with lesser standards.
- More stringent editorial controls are needed to raise the standards of journals. Clearly established editorial standards would help to improve their acceptance as international publications.
- To counteract the problems of finding suitable referees within a developing country, more use should be made of foreign expertise. Local scientists would thus be offered the opportunity of expert attention to their work, the possibility of peer recognition, and thus the reputation of the journal would be improved.
- The editor/publisher should ensure that his/her journal is sent promptly to relevant abstracting and indexing services and incorporated into appropriate databases. The efficiency of the secondary information services today, makes wide circulation no longer necessary for the effective transfer of scientific information. Improved reputation of national journals would then induce local scientists to submit their best papers to them.
- Establishing Regional Training Centres for science editing and writing which could provide facilities for both short-term and long-term training of science editors.
- The publication of regional journals by pooling resources, instead of each country publishing independent journals in various areas of specialization.
- Research programmes should be initiated to study the level and impact of Third World research in the world's scientific journals and on the status and needs of the Third World countries in scholarly publishing.

Some of the above recommendations are, no doubt, difficult to implement. Geographical distances, nationalism and language differences, are all impediments to effective regional cooperation, but these difficulties, though serious, can be overcome.

Scientists in the Third World are often seriously handicapped by lack of equipment and financial resources, lack of access to foreign literature, restriction on traveling and the consequent isolation. The publication of appropriate scientific journals and their gaining wider recognition could act as channels to facilitate communication. Towards this objective, a broader awareness of the existing problems has to be created within the international scientific community, to make the structure of science communications more equitable throughout the world.

■ Nimala R. Amarasuriya

Amber Waves of Teff

Some observers perceive a tiny, little-known, grasslike grain called teff, now grown almost exclusively in Ethiopia, as a potentially important new food for the world market. Ground into flour, it makes a highly nutritious bread that is an Ethiopian staple. Apart from the fact that "there is evidence that the seed has more food value than the grains Westerners consume most often: corn, wheat, barley, and soybeans," there is growing interest in it because of its strong resistance to drought. In an age of rising concern over permanent changes in worldwide weather patterns, writes Shannon A. Horst in *The Christian Science Monitor,* teff will bear watching.

Wayne Carlson of Caldwell, Idaho, is "one of only a handful of commercial farmers outside Ethiopia who are growing, grinding, and selling teff." In less than five years Carlson, who became aware of the grain while working as a biologist in Ethiopia, "has gone from testing a few of the multiple varieties of teff grown in [his] backyard to harvesting 200 acres of four strains and grinding and packaging thousands of pounds of seeds each year. ... [He] already supplies teff flour to a number of Ethiopian restaurants, which have begun springing up in major cities to serve Americans as well as an estimated 50,000 Ethiopian refugees and immigrants," and is now introducing it into the natural foods market. Carlson and his wife and partner, Elizabeth, are also donating part of their output—35,000 pounds of seeds last year — to a relief agency working in Ethiopia, where the "structural food deficit" continues to grow under the "agriculture ... policies of the ... Ethiopian government."

World Development Forum, 30 September 1988

Science takes the stage in Gandhi's India

India's scientific community will this week present an ambitious plan to Rajiv Gandhi, the prime minister, for integrating science and technology into the country's social and economic plans. If the government approves the ideas, they could fit into the country's next five-year economic plan, which begins in 1990.

The plan sets out ways of incorporating research into planning everything from food and housing to industrial development, population control and ecology.

The plan is the work of the Science Advisory Council to the Prime Minister, chaired by C.N.R. Rao [Founding Fellow of the Third World Academy of Sciences], the director of the Indian Science Institute in Bangalore. Gandhi asked the council to suggest strategies for incorporating science and technology into India's national plans up to the year 2001. India made a similar but unsuccessful attempt at this in 1973.

In its report, the council distinguishes between involving science and technology in planning, and planning for science and technology. "For example," says Rao, "huge amounts of money are spent on construction and housing, but little attention is paid to materials." The council's report points out that 60 per cent of the rural population in India will depend on mud and thatch for housing for perhaps the next two or three decades. Polymers, says the report, could improve these materials, making them more durable.

Elsewhere, ways must be found to reduce pollution released into the atmosphere by the millions of two- and three-wheeler vehicles expected on Indian roads in future. Efficient alternatives to wood for cooking in villages are also needed, because the depletion of trees is devastating the environment.

The problems that receive most attention from the council, though, are food production and population control. "We must stop the population juggernaut and increase our production of food grains from 150 million tonnes to 300 million tonnes by the end of the century." The council recommends that the government should designate these two topics as National Technology Missions. The missions are a means to link work between different ministries. Their tasks cover: providing drinking water for every village, immunization, telecommunications, and producing oil seeds that give edible oil.

Population control, in particular, is urgent, says Rao, because an appraisal last year of India's current five-year plan showed that population growth has not slowed as hoped. The council stresses the role that modern telecommunications can play in broadcasting educational programmes about family planning. The role of science and technology in food production will also be crucial, because increased production will have to come from existing land. India needs to develop genetically-engineered crops with higher yields as well as better techniques for the processing and preservation of food.

If all these plans are to succeed, Rao believes that links between government departments and scientific institutions must improve, and each government department should take scientific advice when it draws up its plans. Rao wants departments to have a science adviser. "Currently," says Rao, "the science adviser is at a low level."

Although Rao's council concentrates mainly on science and technology in national planning, it also reviews industry's role in research and development and plans for science and technology. "The health of industrial research and development in India is a matter of great concern today," the council says.

The council's report points out that industry spends just 0.7 per cent of its turnover on R&D, and the government contributes some of this. The R&D that industry does undertake is often poor, says the council.

Rao and the council want the government to establish a body similar to the US's National Science Foundation, which will receive its own vote from the treasury. This organization would set priorities for funding areas of science and technology.

Currently, a body similar to Britain's Science and Engineering Research Council, which is responsible to the Department of Science and Technology, distributes funds for basic research. Other funds for research are distributed separately to large government research organizations, such as the Space Research Organization or the Atomic Energy Authority.

The council says that money is distributed according to the ability of organizations to absorb funds rather than according to planned priorities. They believe that an autonomous body could set national priorities. Rao believes that Gandhi will set up such a body within a year.

The money spent on universities will also have to increase, says Rao. "The universities are being starved of funds. They need money for better buildings, laboratories equipment, electricity and water."

■ Helen Gavaghan (Courtesy: *New Scientist*, 5 November 1988)

Report on a Trip to Pakistan

During the period 30 December 1988 to 4 January 1989, I went on a trip to Pakistan, invited by the organizers of a Symposium on Genetic Engineering and Biotechnology. The Symposium was held on the occasion of the inauguration of a new Centre of Molecular Genetics at the University of Karachi. I went there on the invitation of the Director of the Centre, Prof. Nuzhat Ahmed, and my travel to Pakistan as well as my stay there in the period indicated were taken care of by the organizers.

The Symposium brought together most of the scientists working in advanced biotechnology in Pakistan as well as some from neighbouring countries (particularly India and Bangladesh), and a number of foreign delegates and Pakistani expatriates.

To my surprise, I found great interest among the Pakistani scientists and the Symposium participants in ICGEB, its present status and programmes. In fact, on the inaugural day, I was asked to encourage the establishment of closer links, and from the reactions of many I was convinced that a request for an Affiliated Centre would come from the Government of Pakistan in the near future.

During the Symposium, I also gave a detailed presentation on the results of scientific work performed at our Centre during the last year, which I thought was well received.

In view of the great interest in ICGEB shown by Pakistani scientists, and of the high quality of the work of many Pakistani scientists I was able to witness, I decided to avail myself of the opportunity of visiting other laboratories in Pakistan engaged in biotechnology. At the end of the meeting, I devoted the period from 5-8 January to visit, in particular, the laboratories in Lahore.

In Lahore I visited essentially two centres. First, the CAMB at the University of Punjab. This complex in fact comprises three centres: a Centre for Advanced Molecular Biology, promoted by the Ministries of Education and Health; a Centre for Agricultural Molecular Biology, supported by the Ministry of Agriculture; and a Centre for Applied Molecular Biology, promoted by the Ministry of Industry. The complex is under the direction of Prof. Sheik Riazuddin, a well-known scientist with long training in the United States.

The CAMB Complex is divided in four labs: one lab does work related more to health, in particular, the study of repair mechanisms of damaged DNA. A second lab is involved in research on plant molecular biology and is doing very interesting work, in particular, on the engineering of cotton plants (cotton represents the major cash crop of Pakistan). A third group is involved in the industrial applications of biotechnology, and studies, in particular, metal binding proteins of yeast, Thiobacilli, and microbial degradation of hydrocarbons. Finally, a production centre is producing restriction endonucleases for their own and other national labs' use: they have already a catalogue of 21 restriction enzymes. This group is also studying the toxins of Bacillus thuringiensis, extremely interesting as a biopesticide.

The second lab I visited was the Pakistani Council of Scientific and Industrial Research Laboratory. In particular, I visited the food laboratories where applied work on food processing is performed. I also had extensive talks with the Vice-Chancellor of Punjab and with the Director of PCSIR.

Altogether, the quality of the work done in the different laboratories that I have been able to visit in Pakistan, as well as that done in other laboratories which I could not visit on this occasion, appears in some cases to be extremely good. I would consider, in particular, all the work of Prof. Riazuddin's in Lahore; the work of Prof. Nuzhat Ahmed and her collaborators in Karachi; and the work of Dr. Malik and his collaborators in Faisalabad.

The country has already undergone a remarkable effort in organizing the Lahore CAMB Complex, and is now in the process of starting a new effort in Karachi, with the newly established Centre for Molecular Genetics. The high quality of the scientists working there, helped in some cases by some expatriates, and facilitated by frequent visits to foreign labs, particularly in the USA, is remarkable.

Of course, the scientists suffer from the familiar problems of the developing world, namely, the difficulties in obtaining convertible currencies, in obtaining even with available currencies the most useful reagents, and the somewhat erratic supply of electric power. These scientists have shown in any case a remarkable ingenuity in overcoming these difficulties, an example of which is offered by the production centre for restriction enzymes.

It is to be expected that Pakistan will take again an active role in ICGEB, and I have been assured that a request for an Affiliated Centre will come very soon. In that case, I would view the request very positively and would anticipate that it should be recommended that the Affiliated Centre be a Federation of the different Pakistani labs which are already quite active in the field (CAMB Complex, Molecular Genetic Centre in Karachi, Faisalabad lab).

■ *Arturo Falaschi [Professor A. Falaschi belongs to the UNIDO-sponsored International Centre for Genetic Engineering and Biotechnology (ICGEB) located at Trieste, Italy].*

Science: the Need for North-South Conciliation

With deep political insight, Willy Brandt described North-South relations as "the greatest challenge to mankind for the remainder of this century" and "the two decades ahead of us... fateful for humanity."[1] His enlightening report *North-South: A Programme for survival* was critically timed: "The 1980s could witness even greater catastrophies than the 1930s", a sombre foreboding stemming from the grave inequities dividing the rich North and the poor South.

Today, growing North-South disparities are all too evident. In sharp contrast to the jet-set luxuriant North, Africa's aggregate GDP per capita has actually fallen every year since 1980 and is now 4 percent below its 1970 level. Another example: during 1983, while US farmers were being paid to take nearly 100 million acres of cropland out of production, 450 million people in the world were found to be starving. With little compunction during that year, 30 children were left to die every minute for want of food and inexpensive vaccines, while every minute the world's military budget absorbed US$1.3 million of public treasure.[2] Today, twenty-three countries of the South with 160 million school-age children strive to spend barely enough on education to match the cost of one single nuclear submarine!

Eight years after the publication of *A programme for survival,* the South continues to be faced with many problems. In the realm of science and technology, the North-South chasm presents many disquieting features: the North, sitting on the gleaming wings of science, rejoices in its grandiose successes, while the South provides a multiplying myriad of eyesores as its fledgling science remains precariously perched.

Should developing countries be left to lurch and languish? Should three-quarters of humanity inhabiting our planet be condemned to a perpetual state of sub-human living? Or should the South be helped to its feet with the North abandoning its detached stance? Shouldn't the South's access to science and technology — its membership card into the twentieth and twenty-first centuries — be precipitated for its eventual salvation, and for the unity of the world?

The promise of science

History richly testifies that science and GDP enjoy a fraternal bond and are closely correlated — the more productive a country is in the sciences, the larger its GDP tends to be. Today's science-rich North hosts barely a quarter of the world's population, yet accounts for four-fifths of its income.

The South, in earlier epochs, was a prosperous assemblage of communities. Mesopotamia and the valleys of the Nile, the Indus and the Yellow River, and many later civilizations that sprang up outside the geographical boundaries of Europe and Anglo-America, gainfully nurtured the creative impulse. The citizens of the towns of what is now Iraq were responsible for the fundamental innovations... They reached a mathematical level of achievement not touched elsewhere until the Renaissance.[3]

Much later, before 200 AD, Alexandria had made almost all discoveries necessary for the achievement of modern western civilization.[3] At the advent of the Colombian era, much of North Africa, South and East Asia were both densely populated and highly organized politically, culturally, and for the time, technologically.[4] The South then was called rich and the less innovative North poor. At its prime, Mughal South Asia enjoyed a standard of living higher than that of contemporary Europe. Even in the post-Renaissance period, marking the beginning of Europe's recovery and subsequent mutation of science, trade between the North and South proceeded on an even keel and the two enjoyed a comparable standard of living. The North's sustained ascendancy in science with the contemporaneous decline of the South saw a reversal of fortunes — the poor North turning rich and the rich South becoming poor. Not much later, the South was stripped of its sovereignty and colonized.

Today, as the dazzling post-World War II "Big Science" achievements sustain their momentum, the North marches triumphantly on, while the hapless, poverty-scarred South trudges behind vainly striving to bridge the science gap. If the 1950-1975 trends are any indication, the GDP of the North is likely to double during 1975-2000, and the development gap at the end of the century could end up even wider.[4]

The North-South science divide

The comparative strength of North-South science makes disturbing reading. A 1971 UN study suggested the concentration of 92 percent of the world's scientists in the North, and accounting for over 98 percent of the total expenditure on R&D. At that time, the per capita R&D investment in the South was about 300 times less than in the North. An American scientist commented: "We find that the average American buys at least 100 times as much research every year as the average inhabitant of an LDC [Less Developed Country in the South], a staggering discrepancy." [5] In the 1980s, the situation improved, but not with any appreciable tilt in favour of the developing countries, and just over ten percent of the world's 3,756,100 R&D scientists and engineers constituted the South's strength.[6] Yet they spent only 6 percent of the world's total R&D expenditure of $207,801 million.

The number of researchers per million population — 126 in the South as against 2,954 in the North in 1980[6] — vividly portrays the overweening strength of the North and the infirm, fragile state of "Southern" science.

More exasperating, the minuscule strength of technical manpower in the South is seldom utilized with any appreciable degree of imagination. While a sizeable number of Northern scientists develop new products and contribute directly to the production line, the role of Southern scientists is restricted primarily to teaching and general services. During 1981, 470,200 of the total 660,700 scientists and engineers in the USA, that is 71.2 percent, were employed in the production sector, 96,000 or 14 percent in higher education, and about the same number in general services. The situation in Argentina, which typifies a South setting, was just the opposite: only 1,700 of the 9,500 scientists were employed in the production sector, 5,200 in higher education and 2,600 in general services.[6]

Publications — faithful chronicles of research findings — are a good indication of scientific output. The North contributed 84 percent of papers published in 1973, and 89 percent of all 1973-1978 citations. The inference is not hard to draw.

Science in the developing countries

The South consists of a heterogeneous assemblage of nations with many cultural, ethnic and historic backgrounds. They "characterize themselves as being developed socially and culturally, and as being underdeveloped economically and technically."[7] Their patterns of scientific growth are anything but uniform. Some are extremely backward, their amorphous science presenting a picture of what has been called a "research desert"; others have made a beginning and have marginally assimilated science; and a few have covered considerable ground and spark a glimmer of hope.

Five Southern countries which offer hope — China, Brazil, India, the Republic of Korea and Argentina — have made promising advances and, with a sustained ardour for R&D, may well alter the global science scene by the turn of the century. China, in particular, has made substantial headway: she has successfully contained her population growth, an otherwise serious impediment for development, and sensibly scaled up her R&D investment. Of late, the industrial units in China that were going into the red are being infused with new vigour by commissioning scientists to modernize and improve them. Thus scientific advice has turned 235 factories in Sechuan province that were losing money into profitable ones and helped the finances of another 7,716.

The Chinese experiments in soft technologies like biogas are of great interest to other developing countries with predominantly agricultural economies. Tens of thousands of biogas plants in villages in China have helped to substantially reduce the energy deficit in the rural sector.

India is yet another country that has shown the way to promote science and technology under depressed economic conditions faced by most developing states. It is perhaps the only such country that has started investing 1 percent of its GDP in Research and Development. Some of its research institutions compare in excellence with those of the North. Even in the so-called "Big Science" fields in which developing countries hardly venture, India has made some advances. She has, for instance, built her own cyclotron in Calcutta. Though it is not as large a machine as the giant accelerators in Europe and the USA, nevertheless, a cyclotron built indigenously and kept in operation is no mean achievement for a developing country.

A second group comprising Pakistan, Bangladesh, Malaysia, Singapore, Turkey, Egypt, Mexico and Venezuela have a corps of scientists currently approaching criticality. The investments in science in these countries are still fairly low and far below the magic figure of 1 per cent of GDP recommended at various UN forums. Some pockets of excellence do exist, as in Pakistan, but science cannot move forward on a broad front with generally low funding and resources.

The third group consists of the Islamic Republic of Iran, Iraq, Jordan, Lebanon, Indonesia, the Philippines, Sri Lanka, Thailand, Vietnam, Algeria, Ghana, Kenya, Morocco, Nigeria, the Sudan, the United Republic of Tanzania, Chile, Colombia and Peru. Their research effort is still fragmented though some individual scientists are outstanding and highly active.

The second and third groups have marginally assimilated science and, with organized help from the rich world's scientific communities, may take off in a short span of time.

The form and framework of science in the remaining 60 Southern countries which live below the poverty line, is too frail and amorphous; only Herculean efforts could retrieve their position.

The scene in 2000 AD

A comprehensive global R&D survey undertaken by Jan Annerstedt for the OECD and the Research Policy Institute at the University of Lund, Sweden, suggests that during one single decade, the South's R&D expenditure may increase by 50 percent. If we assume that the South's R&D manpower were to grow by the same proportion as its R&D expenditure and the same rate of increase were to be maintained over the rest of the century, the South will be "well along the way to achieving parity with the industrialized countries by the end of the century in a purely quantitative sense (there would still be enormous imbalances from one country to another, just as there are among industrialized countries)."[8] This is partly attributable to a marked trend of rapid growth of trained manpower in some countries of the South, and partly to near-constant growth curves in many countries of the North in the last few years.

But while quantitative successes might place the South on near-even keel with the North by the year 2000, the qualitative gains would largely remain unmatched by the South and its helpless reliance on the industrial countries is likely to continue. Much to their discomfiture, the leading edge of the current generation of microelectronic technology remains an elusive frontier for even the leading countries of the South.

Biotechnology, a recent arrival on the world scene, offers unique opportunities to the South for the solution of problems that have lingered on for centuries — problems of food, health, energy, and many more. But it also poses serious challenges to the agricultural economies of the South. With most of biotechnology research concentrated in transnational corporation laboratories, improved methods of agricultural and industrial production in the North could well displace the major exports of developing countries. For example, fructose made from corn or maize, has already appeared in the markets of the North as a likely replacement for sugar. Developments in biotechnology might lead to a slow erosion of markets for many of the South's primary products, and their adverse effects will be felt not only on the balance of trade of such affected countries, but even more keenly by poor labourers involved in the production of such products.[9] The South would have to more than match its wits with the North in the field of biotechnology. The task is daunting, since (Northern) multinational corporate interests are at stake.

Genesis of the North's indifference

Ninety percent of the world's manufacturing capacity is concentrated in the developed world and explains the strong corporate interests that globally interact in commerce, trade and science transfer. The transnationals or multinationals are trading republics operating on a massive scale as a commercial manifestation of the North's scientific supremacy. Sales revenue of the US-based giant General Motors, for example, can be favourably compared with the Gross Domestic Product of a country like Austria. The whole of tropical Africa (excluding the northern group of countries and South Africa) does not greatly exceed the sales of the largest US company.[4]

As the science-based manufacturing capacity of the North turns out value-added finished products, the trade balance continually alters to the disadvantage of the South. In the mid-1970s, trade between North and South grew to $277 billion, making up about 39 percent of the world's total, but the major share of the profits was gobbled up by the North. And understandably so. The prices of primary products continue to dwindle while those of finished products unalterably soar higher and higher. "Year after year I have seen the cotton crop from my village in Pakistan fetch less and less money; year after year the imported fertilizer has cost more...", observes one perceptive man from the South. "Some courageous men have spoken against this. Paul Hoffman called it a 'subsidy, a contribution paid by the underdeveloped countries to the industrialized world.' In 1957-1958, the underdeveloped world received a total of $2.4 billion in aid and lost $2 billion in import capacity (through paying more for the manufactured goods it buys and getting less for what it sells), thus washing away nearly all the sums received in aid."[10] The trend bemoaned by Salam continues. An exasperated Michael Manley, the ex-prime Minister of Jamaica, protested not much later: "In the 1950s, 10 tons of sugar brought a Jamaican farmer a Ford tractor. In the 1970s, the same tractor costs 25 tons of sugar. Why? Is it that the Jamaican peasant is subsidizing by a factor of 100 percent the social security and welfare of Ford plant workers?" Critical of the seriously disconcerting trend, the Rio Declaration made the incisive point: "They [the North] have used the power provided by science and technology to pursue policies shaped by selfish interests over the world oceans, and they are squandering a vast fraction of mankind's resources, in scientific manpower as well as materials, in stockpiling of weapons of mass destruction."

More recently, the North has been accused of *intellectual imperialism.* What are the elements of this imperialism?

(i) Outright and indeed statutory denial of certain vital technologies under the pretext of non-proliferation, Glenn Amendment, etc.;

(ii) Subtle pressures on universities to close certain doors to "undesirable" nationalities. The US Academy of Sciences has in fact protested against such discriminatory practices;

(iii) Raising the fees for foreign students, notably in the UK;

(iv) Trying to pass on outmoded and low technology to the LDCs under the garb of "appropriate technology";

(v) Manipulating international markets to depress the prices of raw materials;

(vi) Leaving the low technology and low value-added manufacturing — like basic materials — to the South. The North goes on to higher and higher value-added (and also environmentally cleaner) industries.

Can the UN help?

The United Nations has shown laudable concern for international science and has tried to promote R&D effort on a global scale to live up to its world-body image. In the absence of a universal science policy, the UN perception of some global problem areas has not been entirely without gains: it has helped to define a strategy and to frame well-meaning long-term programmes. Some of the UN schemes have won accolades, and deservedly so. One example of this was the establishment of the International Centre for Theoretical Physics, in Trieste, Italy, an institution with considerable international stature serving as a European rendezvous for physicists of the developing countries to re-establish their rapport with the frontiers of latest knowledge, to "plug in" to the current excitement and sample the latest ideas.

But the North's apathy for Southern Science has watered down many well-meant UN initiatives. Two international conferences on Science and Technology (1963 and 1979) yielded little and only served to reveal the North's indifference. In the words of a South participant: "It seemed that they preferred the scientific and technological effort of the United Nations to remain weak and fragmented within the system. There appeared no desire on their part to share technology with the developing world except through the existing system of licensing... The net legacy of this conference was the creation of an eighteen-man advisory Committee on Science and Technology. We met for eleven years — twice a year; after eleven years' labour, we have recommended yet another United Nations Conference on Science and Technology... to meet and create the same Science and Development Agency we proposed fifteen years ago."[10] At the 1979 UN Conference, the South vainly urged for international support to raise its $2 billion R&D expenditure to 4 billion and got only one-seventh of the sum requested. Yet even this slashed allocation has not been fully realized. Lately, a "world without the United Nations" campaign has been orchestrated.

A silent message comes through. In the words of Ward Morehouse, *"...notwithstanding the diversity and good intentions of various UN initiatives, the dominant factors shaping advances in science and technology and their international flows are largely unrelated to, and unaffected by, what happened within the UN system. The major impetus of change comes from the R&D budgets of the major industrialized countries and multinational corporations, now increasingly linked to universities in advanced countries. These programmes are fashioned entirely without reference to the UN system or to the interest of Third World countries or peoples."*

The North's obligation

The science of the North can be used as the great equalizer to give each country in the world the opportunity to feed its people, to house them, to allow them to enjoy life in all its wondrous aspects, and to give them the feeling of pride in intellectual achievement. "In the United States, we used to talk of the gun as the great equalizer, the method that American cowboys employed to take care of bullies. Today, I believe the greatest equalizer is science," commented Kurt Salzinger, president of the New York Academy of Sciences.

Rescuing the South would not be entirely without gains for the North: collaboration in research in regions which are rich in the natural resources of plants, animals and minerals, and in countries which are uniquely placed in relation to incident solar energy and the geographic and magnetic equators, would be mutually beneficial. *Not all areas of science, not all accomplishments, not all discoveries to be made in future, as Kurt Salzinger has predicted, will be made in big or expensive science.*

Among the broad areas for initial North-South collaboration, the following appear most attractive: (a) biotechnology, particularly in relation to medicine; (b) genetic improvement in agriculture; (c) mass propagation techniques in agriculture; (d) post-harvest food preservation; (e) survey of natural resources; (f) soft technologies for energy production; (g) electronics and computer technologies; (h) health and sanitation; (i) rural industrial development; (j) laser development and application, e.g. in microsurgery, precision manufacturing, etc.; and (k) optical communication.

The North is also morally obliged to erase some of the present scientific and technological imbalances which are largely its own doing. It is hard to deny that "for most of the sovereign states of the world, the length of time and the degree of intensity to which they have been subjected to European influence has much to do with their present political, economic, material and technological levels and systems of organization." [4] Science in the battered colonized world was left to languish and decay. Lord Macaulay, for instance, strove to give India the best Britain could offer in the way of an educational system, but this did not include science and technology.

Historic compulsions too suggest the same course. In the long run, the North's indifference to science development in the South will be counterproductive for the North itself. Throughout human history, science has never flourished under restrictions, be they of religion (Mediaeval Europe), politics (Nazi Germany) or frontiers (modern USA). It has been rightly said that "the technical opportunities, though certainly helping to liberate mankind in many ways, exacerbated some of the world's ancient troubles, and scientific achievements have scarcely been matched by political ones. In the late 1970s, it seemed possible that Western civilization might collapse before the end of the century, either from the onslaught of irrationality without or the failure of nerve within." [3] It is in the interest of the North to show greater respect for human development which needs the science of values, rather than put all its stakes in technical development, which is not total development and does not settle the major problems of politics, economics and war, but only raises such issues to a new pinnacle of desperation.[7]

The Marshall plan and its successes have set a shining precedent of international assistance, an outstanding example to emulate. A total of $32 billion — 2.7 percent of the then GDP of the USA — transformed war-ravaged Europe, setting off a chain reaction of prosperity for the donor and the recipient. The same applies to North-South collaborative schemes: wholesome results would surely ensue but over a longer timespan, given the South's multifarious problems. The *International Herald Tribune* has in a timely way commented: "...there is much that the North could do. It could start to raise the meager 0.3 percent of overall GDP that it devotes to aid, particularly through the International Development Association. It could move prudently toward faster growth and speedily toward freer trade for the products that the poor can produce. Above all, it could stop sermonizing and show greater tolerance for the economic institutions favoured by struggling governments in the South... North-South relations would improve if the rich showed more understanding of the pressures faced by the poorer countries at home." [11] Countries today are so interdependent that "it is impossible for the two hemispheres to follow divergent trends for long," the *Tribune* concludes.

Southern science: how to meet the challenge

The 1960s marked the "decade of awareness" — a period of conferences, workshops, theoretical discussions — to impress upon planners the importance of science in national development; and the 1970s was envisioned as a "decade of action". Lamentably, little "action" was generated during the 1970s, and many scientists in the developing countries suffered the agony of inertia — allround frustration. True, now and then, a few individuals did make a spectacular dash to confirm that streams of innovation had not fully dried up, but the trend failed to gather steam.

The recent scenario has been little different, save in one respect: the South has come to realize that South-

South cooperation, in addition to North-South initiatives, can also pay off, however inappreciably. Many regional groupings have sprung up, such as the Southern African Development Coordination Conference (SADCC), the Gulf Cooperation Council (GCC), the Latin American Energy Organization (OLADE), the Caribbean Community (CARICOM), etc. Regional science academies have also emerged to foster closer ties in scientific pursuits. The Academy of Latin America, the African Academy of Sciences, the Islamic Foundation for Science, Technology and Development, are just a few examples. Two years ago ALECSO — the Arab League Educational, Cultural and Scientific Organization (founded 1970) — launched a major project of drawing up a "strategy for science and technology in the Arab World." The SARC countries — Pakistan, Bangladesh, India, Sri Lanka, Bhutan, Maldives and Nepal — have prepared an "inventory" of research institutes in member countries to serve as a basis for establishing cooperative links. G.B. Marini Bettolo, president of the Accademia Nazionale delle Scienze detta dei XL, Towards the Year 2000 (Italy), has commented: "Most academies [in the South] have overcome their difficulties and are also no longer obsolete traditional institutions of prestige but very active bodies." A good omen. But more importantly, a new institution, the Third World Academy of Sciences (TWAS), has emerged with its headquarters at the International Centre for Theoretical Physics (ICTP), in Trieste, Italy. The Academy is the brain-child of Nobel Laureate Abdus Salam whose personal eminence and astute stewardship have played a major role in overcoming the frustrating isolation of Southern physicists. The ICTP experiment has been a great success. Salam heads the TWAS as its president and his efforts to give South science a fillip will, hopefully, succeed. The North scientists and academics too should rally round him.

At the 1985 Conference on South-South and South-North Cooperation in the Sciences, sponsored by the TWAS at Trieste, a large number of Northern planners, scientists and academicians pledged to support TWAS in no uncertain terms. Said A. Guinier of the French Academy of Sciences: "The advice of the TWAS will improve the efficiency of the North-South and South-South exchanges and increase their relevance to the real needs of the developing countries... the Académie des Sciences is anxious to establish close relations with TWAS in order to exert our effort in the ensemble of the cooperation between developed and developing countries." Kurt Salzinger, president of the New York Academy of Sciences, assured: "The New York Academy of Sciences stands ready to work with the Third World Academy."

As the Southern scientists continue their often-frustrating and seldom-rewarding scientific plod, they should not lose heart but instead seek consolation in the knowledge that the irritating problems confronting them today are nor peculiar to their own setting but were once an annoying feature of Northern science at its formative phase.

The flowering of science was unfailingly obstructed and stifled when the North was entrapped in poverty. The changeover from a feudal to a science-oriented society was not spontaneous, the blueprints precipitating the Industrial Revolution and the science culture were not self-generating, pre-existent, or interwoven. The going was rough, over a tortuous winding road.

Even the post-World War II "Big Science" was not free from failings. Many mistakes were committed but camouflaged by the explosive rate of development. As late as the end of the sixties, science policy in Europe was still in its infancy, and "seeking its terminology and methods."[12]

Though hardly symptomatic of the time, scientists in the USA often fret today that many bright people "who would otherwise enter our science arena, are passing it by without any real exposure to its attractions."[13] There is also considerable resentment that "economists who often offer such temporary and shaky solutions are among the President's most favoured and visible advisers while scientists who are specially qualified to develop adequate knowledge and understanding of the issues themselves, struggle to be heard."[13]

In the prodigious struggle of the North, one which is still continuing, there are lessons for Southern scientists. Failures are a necessary prelude to success. A whole-hog commitment, an unrelenting effort, should be their prime undertaking. The emergence of Southern multinationals and their corporate interaction with the old and well-entrenched transnationals — trading empires and storehouses of valuable scientific know-how — also leads one to shed some pessimism about the future of Southern science.

Whose responsibility?

Rescuing Southern science from its present abyss is the responsibility of the three main actors on the world scene — the North, the South, and the UN. Each one has a role to play. In a world of multi-polarity and increasing complexity, such a futuristic perspective appears fanciful, though rationally opportune, if one seriously contemplates the prospects for a livable world. Brandt, for one, was bold enough to suggest to at least explore the realm of the possible: "Many people in government, and elsewhere, may consider this to be the worst possible moment for radical changes. How can industrial nations preoccupied with grave problems of their own be expected to make far-reaching and bold moves to intensify cooperation with the developing world? But we believe that it is precisely in this time of crisis that basic world issues must be faced and bold issues taken." Uplifting the state of Southern science today is certainly a basic world issue, a pressing one. Divested of science, "technology transfer" alone would be a formalistic exercise in abstraction and would hardly accomplish anything of lasting value. It would be like the gift of a decorative house-plant without its roots — it would look beautiful for a day or two, but would surely wither away.

■ Akhtar Mahmud Faruqui (Courtesy: *Impact of science on society,* UNESCO)

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Gains from Australian Scientific Research

Rivers in four Commonwealth countries clogged by a deadly weed began to flow freely after Australian scientists got rid of the weed, using a method they developed after early work by a Commonwealth body based in the Caribbean. The weed afflicting the rivers in Australia itself and Botswana, Papua New Guinea and Sri Lanka was *Salvinia molesta,* a fast-growing fern brought to Australia as an aquarium decoration. It soon escaped to cover much of Australia's tropical and subtropical freshwater with thick vegetation.

Building on the early work by the Commonwealth Institute for Biological Control, based in Trinidad and Tobago, Australian entomologists isolated a previously unknown species of weevil, a type of beetle, which attacked salvinia. The beetle destroyed about 50,000 tonnes of salvinia within ten months when set loose on the water reservoir at Mount Isa, a large mining town in Northern Queensland.

Dr. Barry Filshie of Australia told this story to the 15th biennial meeting of the Commonwealth Science Council (CSC) in Lagos, the Nigerian capital, last November. He cited this as an example of how Australia cooperated with other Commonwealth countries in science and technology in tackling common problems.

Dr. Filshie is in charge of the Centre of International Research Cooperation of Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO), based in Canberra. He is the Australian representative on the CSC, the main inter-governmental agency promoting scientific cooperation in the Commonwealth.

Research by CSIRO scientists on the control and management of another aquatic weed, water hyacinth, benefited many African countries and played an important role in a CSC regional programme for Asia-Pacific concerned with the weed.

As Australia celebrated its bicentenary in 1988, the CSC invited Dr. Filshie to address its Nigeria meeting on highlights of 200 years of science and technology in Australia.

He said that in its short history, Australia had become a leading nation in science and technology, especially in agricultural research. Australia, he pointed out, was the only developed country engaged in tropical agricultural research for its own needs. It was willing to share what it learnt, particularly with tropical Commonwealth countries.

Dr. Filshie said Australia shared the process whereby the Commonwealth provided a vital source of coordination, guidance and responsibility for young and future nations working to improve their living standards.

"Australia — because of our relative abundance of natural resources — has played an increasingly important role in this process. Over time, we have become a source rather than a recipient of aid and expertise." Australia had bilateral arrangements in science and technology with other governments, but no formal treaties existed between it and most other Commonwealth countries, he said. Yet, a quarter of its overseas scientific links were with Britain alone. "The fact that no formal bilateral mechanisms are needed for scientific cooperation between Australia and other Commonwealth countries is a healthy sign that the Commonwealth is, indeed, alive and well."

Dr. Filshie said Australian agricultural research was particularly relevant to Africa, the setting for the CSC meeting. "This is the first time that I've been to West Africa," he said. "For me me this is a new experience and an educational one. Australia has a tremendous amount to offer Africa, especially in agricultural research, but we need to be aware of their needs. This meeting gave me a rare opportunity for interaction with senior African colleagues and to understand their needs as well as their problems. It will allow me to argue their case better (for Australian support) when I get back home."

He expressed concern over lack of government funding for scientific research in Australia as well as in many other countries. This "crisis in funding" extended to international scientific bodies, including CSC.

His message to the Council was that it should blow its own trumpet a little and make its achievements better known to ensure continued support for its work. "It is time for the Council to raise its collective voice — much louder than it has before — and proclaim to our Commonwealth leaders the importance and value of its work."

He added: "Publicity for its programmes and achievements would bring it general recognition and, we hope, help to attract funds." He noted that several non-Commonwealth agencies had supported CSC projects. (These include the United Nations Environment Programme, Unesco, HABITAT, the Ford Foundation and the International Board for Plant Genetic Resources.)

"This just goes to show that these organizations regard the Council's activities as worthwhile and that they think its projects are good and well thought out."

■ Asif Khan

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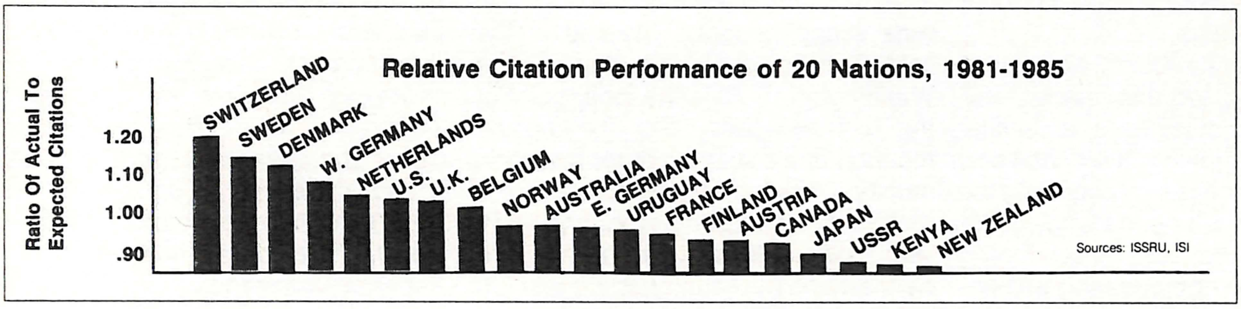
Switzerland, Sweden, Denmark Rank Highest In High-Impact Science

A trio of relatively small Western European nations heads a recently published list of countries that produce high-quality basic research. The study, undertaken by the Information Science and Scientometrics Research Unit (ISSRU) of the Hungarian Academy of Sciences in Budapest, found that the scientists of Switzerland, Sweden and Denmark produced papers having significantly greater impact than expected, based on the average citation rates of the journals in which each paper was published.

By the same measure, West Germany, the Netherlands, the United States, the United Kingdom, and Belgium also recorded better-than-expected performances, but not as great as those of Switzerland, Sweden and Denmark. France, Japan, the Soviet Union, and nine other countries rounding out the top 20 showed lower-than-expected performances.

The ISSRU, using the data of the Institute for Scientific Information's *Science Citation Index* for the period from 1981 to 1985, compared the actual number of citations per paper received by publications from a particular nation to the expected number of citations per paper. Citations were counted from 1981 to 1985, so that the effective citation period varies from zero to five years.



"The indicators so obtained," write the study's authors, "provide a complex measure of medium range citation impact and citation immediacy for a considerably large population of papers, even for small countries." (T. Braun, W. Glänzel, A. Schubert, "The newest version of the facts and figures on publication output and relative citation impact of 100 countries, 1981-1985," *Scientometrics*, **13**, (5-6), 181-8, May 1988).

The accompanying table lists the top 20 nations in the ISSRU's ranked list of relative citation performance. The relative citation rate for each is the ratio of actual to expected citations. A score of 1.0 would mean that a nation's publications received exactly the number of expected citations. A score above 1.0 signifies a higher than expected citation performance; below 1.0, underperformance.

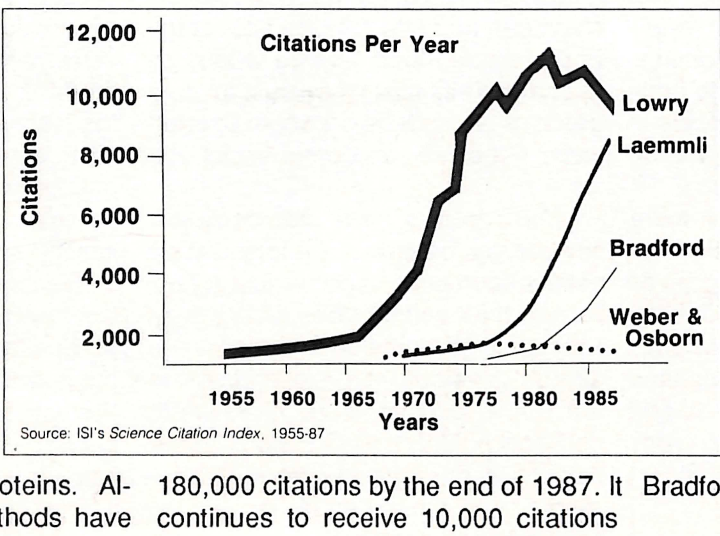
Ranking seventeenth and eighteenth, respectively, Japan and the Soviet Union are somewhat handicapped in this analysis by the relative inaccessibility and lower citation rates of articles written in Japanese or Russian.

"The most striking feature [of this study] is the outstanding position of a series of small West-European countries (Switzerland, Sweden, Denmark, The Netherlands, Belgium, Norway)," observe the authors. They noticed a similar phenomenon in their previous study of the period 1978 to 1980.

■ Courtesy: *The Scientist*, 8 August 1988

The Four Most Cited Papers

It will surprise few that methods papers lead the list of the most cited scientific articles ever — at least those tracked in the Institute for Scientific Information's *Science Citation Index*, 1955 to 1987.



Source: ISI's *Science Citation Index*, 1955-87

"The Lowry paper," as it is known, stands head-on-shoulders above all others. This 1951 article by Oliver H. Lowry, Nira J. Rosenbrough, A. Lewis Farr, and R.J. Randall, published in the *Journal of Biological Chemistry*, **193**, 265-75, reported an improved procedure for measuring proteins. Although more sensitive methods have since been introduced, it still ranks as the King of the Classics, with over 180,000 citations by the end of 1987. It continues to receive 10,000 citations per year.

Why is this the most cited paper? Lowry observed: "It filled a need in the beginning — and a lot of people measure proteins. Once it became established... other people may have thought it was the method to use, or at least checked the procedure they were using against it."

The accompanying chart plots citations per year to the Lowry paper, and those to the second, third and fourth ranking Citation Classics.

Citations to the Lowry paper began to slow in the mid-1970s. At about the same time — in 1976 — Marion M. Bradford published "A rapid and sensi-

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Why Scientists Should Start Playing The Political Game

The National Academy of Sciences' recent report on the behavioural and social sciences* reveals that federal support of this domain of sciences has declined over the past 16 years, even though support for other areas of science has grown substantially. The report makes a good case for the public benefits of research in behavioural and social sciences and argues for increased funding. This argument, however, is likely to fall on deafened ears, as almost every segment of the scientific community has pleaded for more funds in recent years.

What can behavioural and social scientists — or, for that matter, any other scientific disciplines in similar straits — do to promote their case better? The answer lies in recognizing the political realities of science funding. We cannot escape the fact that conducting research, however pioneering and important, is simply not enough to ensure fiscal health. *Scientists must also play a political game to win friends and support in high places.*

To begin with, scientists can help themselves attract research funding by doing more to harness the power of the press, and thus tell the public and public representatives about their research.

For a successful example of this strategy, witness the neuroscience community. Neuroscience, which emerged as a distinct discipline only in the past 20 years or so, has quickly captured both public imagination and congressional support. Each year brings forth a spate of books popularizing neuroscience. Studies of the brain are among the most popular topics in the growing coverage of science by newspapers and public television.

Is neuroscience intrinsically more interesting to the lay person than experimental psychology, which receives far less coverage? Quite the contrary. People are intrigued by neuroscience largely because it helps us understand human behaviour, both normal and disordered. Experimental psychology addresses at least as directly as neuroscience the nature of perception, cognition, action, and social behaviour. Psychophysical research is also stimulating new approaches to artificial intelligence. It is not hard to interest lay people in the development of machines that will identify visual objects, and learn from experience.

Why has neuroscience been so successful in attracting public attention? One reason is the remarkable cohesiveness of this community, which is especially impressive in view of the wide range of topics covered in the field. The Society for Neuroscience in Washington, D.C. is the focal point of this cohesiveness, and the annual meeting is a major event for the community. The society operates a press room at the annual meeting, and every year many articles appear in newspapers around the country as the result of the meeting. The society also organizes biennial workshops for science writers, providing another route for disseminating information. In addition, medical schools now routinely call press conferences to announce "breakthroughs" in biomedical or neuroscience research.

Influencing the news media requires more than just a press room at annual meetings or press conferences, however. Personal and trusting relationships between scientists and writers must be created. In addition to promoting media coverage, such relationships can facilitate balanced coverage. For example, good science writers often call on scientists they trust for suggestions and advice on whom to interview, especially on controversial topics.

Compared to the neuroscience community, behavioural and social scientists have been sadly remiss in publicizing their contributions. There is no strong single society to monitor research developments, disseminate information, and organize newsworthy gatherings. Only a few individual scientists have attempted to work with the media. And how often do universities hold press conferences about dramatic advances in experimental psychology? I suspect that many other disciplines could profit from the neuroscience example.

The scientific community as a whole has also learned that the availability of federal funds for a field of science depends on persuading Congress of the public benefits of research in that field. This requires considerable and continual effort. Each scientific discipline must keep track of critical issues and events in Congress — especially appropriations. And when the key issues arise, scientists must be ready both to provide background information and to gain Congress' ear with personal testimony. *The physics and neuroscience communities, in part because of strong professional societies, have been especially successful in mobilizing their scientists and bringing in Nobel laureates and other luminaries to testify before Congress.*

Another way of gaining influence is through organizations that benefit from research applications. Voluntary groups concerned with neurological diseases, for instance, have greatly helped neuroscientists lobby for increased support. Experimental psychologists should join with potential users of their research to lobby for funds. For example, research on human perception and research to develop machines that can recognize speech and visual sciences are likely to have a large impact on industry and economics in coming years. Recent developments in cognitive psychology promise to revolutionize aptitude testing in schools and industry. Members of Congress are just as interested as you or I in how their children are selected for college, medical school, and law school.

Behavioural and social scientists are trying to get the message out. The Federation of Behavioural, Psychological and Cognitive Sciences (an effective organization badly in need of shorter name) operates a luncheon seminar series on Capitol Hill. Mem–

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* *The Behavioral and Social Sciences,* National Academy Press, 1988.

Mrs. Thatcher's Address to the Royal Society*

It was at your annual dinner of 1972 that I had the privilege of speaking to *your* Society in my capacity as Secretary of State for Education and Science. This is my first opportunity *as Prime Minister* to address *our* Society of which I am so proud to be a Fellow. I confess that I am quite pleased that I didn't continue my work on glyceride monolayers in the early 1950s or I might never have got here at all!

But I am reminded of a reviewer of Solly Zuckerman's recent autobiography who said that as a rule scientists rarely make successful politicians!

From *my* experience let me say this: in today's world it is very good for politicians to have had the benefit of a scientific background. And not only politicians. *Those who work in industry, in commerce, in investment. Indeed, so important has it become that I believe we are right to make science a compulsory subject for all schoolchildren.*

Over its 343-year-history, the Royal Society has become the leading British academy of science with over 1000 Fellows and, in keeping with your international tradition and standing, nearly 100 Foreign Members.

As you know, Mr. President, we have tried in Number 10 Downing Street to recognize the enormous contribution that scientists have made and are making to our prosperity and intellectual reputation as a people, by showing prominently portraits of eminent scientists among our pictures of those who have done so much for our country. And so we have Michael Faraday in the hall. We have Isaac Newton in the dining room, and paintings of Robert Boyle, Humphry Davy, Edmund Halley and Dorothy Hodgkin in our other rooms. Indeed we have just redecorated No. 10 and have changed some of the other pictures so there are several spaces vacant! I should like to fill them during my years of office by more of today's scientists. Alas we have found that many distinguished scientists do not devote time to being painted by distinguished artists on canvases of the right size! I should be grateful if you could rectify this state of affairs.

Everyone here, and no one more than myself, will support Whitehead's statement that a nation which does not value trained intelligence is doomed.

Science and the pursuit of knowledge are given high priority by successful countries, not because they are a luxury which the prosperous can afford; but because experience has taught us that knowledge and its effective use are vital to national prosperity and international standing. But we need to guard against two dangerous fallacies: first, that research should be driven wholly by utilitarian considerations; and second, the opposite, that excellence in science cannot be attained if work is undertaken for economic or other useful purposes. We should not forget that *industry* has had its share of Nobel prizes. AT&T for the transistor; IBM for warm superconductors; EMI for X-ray tomography. It is time we won some more.

In a January White Paper, and on various occasions since, this Government has made it clear that the *commercial* development of scientific principles should mainly be the task of industry.

It is in industry's own interest to pursue the research needed for its own business, collaborating with partners as necessary.

Industry could also help our academics to spot commercial applications when they arise unexpectedly during the course of more basic work. There are too many stories of British discoveries being published without patent protection, only to make money for foreign lands.

Industry is becoming more scientific-minded: scientists more industry-minded. Both have a responsibility to recognize the practical value of the ideas which are being developed.

Basic science

In your Dimbleby lecture on knowledge and its power, Mr. President, you stressed the importance of basic science in a challenging way. You will know from our joint attendance at the new Advisory Council on Science and Technology (ACOST) that this is a view which I share.

It is mainly by unlocking nature's most basic secrets, whether it be about the structure of matter and the fundamental forces or about the nature of life itself, that we have been able to build the modern world. That is a world which is able to sustain far more people with a decent standard of life than Malthus and even thinkers of a few decades ago would have believed possible. It is not only material welfare. It is about access to the arts, no longer the preserve of the very few, which the gramophone, radio, colour photography, satellites and television have already brought, and which holography will transform further.

Of course, the nation as a whole *must* support the discovery of basic scientific knowledge through Government finance. But there are difficult choices and I should like to make just three points.

First, although basic science can have colossal economic rewards, they are totally unpredictable. And therefore the rewards cannot be judged by immediate results. Nevertheless, the value of Faraday's work today must be higher than the capitalization of all the shares on the Stock Exchange!

Indeed it is astonishing how quickly the benefits of curiosity-driven research sometimes appear. During the Great War, our then President, J.J. Thompson, cited the use of X-rays in locating and assessing the damage of bullet wounds. The value of the saving of life and limb was beyond calculation, yet X-rays had only been accidentally discovered in 1895! *Second, no nation has unlimited funds, and it will have - even less if it wastes them.* A commitment to basic science cannot mean a blank cheque for everyone with — if I may put it colloquially — a bee in his bonnet. That would spread the honey too thinly.

* The British Prime Minister delivered the address at the Royal Society's Annual Dinner on 27 September 1988.

So what projects to support? Politicians can't decide and heaven knows it is difficult enough for our own Advisory Body of Scientists to say yea or nay to the many applications. I have always had a great deal of sympathy for Max Perutz's view that we should be ready to support those teams, however small, which can demonstrate the intellectual flair and leadership which is driven by intense curiosity and dedication.

A good researcher is keenly competitive and wants to be first. The final stage of the race for the DNA structure was as exciting as any Olympic marathon. The natural desire of gifted people to excel and gain the credit for their work must be harnessed. It is a great source of intellectual energy.

We accept that we cannot measure the value of the work by economic output but this is no argument for lack of careful management in the way specific projects are conducted. The money is not for top-heavy administration but for research. If only we could cut some £20 million from *very* large scale projects — where the non-scientists sometimes outnumber the scientists —*that* money could provide support for hundreds of young researchers whose requirements are measured in thousands of pounds.

My third point is that, despite an increase in the basic science budget of 15 percent in real terms since 1979, the United Kingdom is only able to carry out a small proportion of the world's fundamental research, and that of course is true of most countries.

It is therefore important to encourage our own people to be aware of the work that is going on overseas and to come back here with their broadened outlook and new knowledge. It is also healthy to have overseas people working here. We already do much to encourage international travel and teamwork.

The Royal Society has 44 exchange agreements with learned societies overseas, leading to 1000 exchanges a year. Through SERC (the Science and Engineering Research Council), the Government funds some 120 postdoctoral fellowships, half of which are tenable overseas for one year and often more.

The recent visits of the Presidents of the Soviet and Chinese Academies and the increased exchanges to which they will lead are most welcome. The Society's work in promoting internationalism has my strongest support.

Mr. President, this country will be judged by its contribution to knowledge and its capacity to turn that knowledge to advantage. It is only when industry and academia recognize and mobilize each other's strengths that the full intellectual energy of Britain will be released. In this respect we greatly appreciate your work and that of Sir Francis Tombs, Chairman of ACOST.

The environment

Mr. President, the Royal Society's Fellows and other scientists, through hypothesis, experiment and deduction, have solved many of the world's problems.

- Research on *medicine* has saved millions and millions of lives as you have tackled diseases such as malaria, smallpox, tuberculosis and others. Consequently, the world's population, which was 1 billion in 1800, 2 billion in 1927, is now 5 billion souls and rising.
- Research on *agriculture* has developed seeds and fertilizers sufficient to sustain that rising population, contrary to the gloomy prophesies of two or three decades ago. But we are left with pollution from nitrates and an enormous increase in methane which is causing problems.
- *Engineering and scientific advance* have given us transport by land and air, the capacity and need to exploit fossil fuels which had lain unused for millions of years. One result is a vast increase in carbon dioxide. And this has happened just when great tracts of forests which help to absorb it have been cut down.

For generations, we have assumed that the efforts of mankind would leave the fundamental equilibrium of the world's systems and atmosphere stable. But is it possible that with all these enormous changes (population, agriculture, use of fossil fuels) concentrated into such a short period of time, we have unwittingly begun a massive experiment with the system of this planet itself.

Recently three changes in atmospheric chemistry have become familiar subjects of concern. The *first* is the *increase in the greenhouse gases*— carbon dioxide, methane, and chlorofluorocarbons — which has led some to fear that we are creating a global heat trap which could lead to climatic instability. We are told that a warming effect of 1°C per decade would greatly exceed the capacity of our natural habitat to cope. Such warming could cause accelerated melting of glacial ice and a consequent increase in the sea level of several feet over the next century. This was brought home to me at the Commonwealth Conference in Vancouver last year, when the President of the Maldive Islands reminded us that the highest part of the Maldives is only six feet above sea level. The population is 177 000. It is noteworthy that the five warmest years in a century of records have all been in the 1980s — though we may not have seen much evidence in Britain! The second matter under di cussion is the discovery by the British Antarctic Survey of *a large hole in the ozone layer* which protects life from ultra-violet radiation. We don't know the full implications of the ozone hole nor how it may interact with the greenhouse effect. Nevertheless, it was common sense to support a worldwide agreement in Montreal last year to halve world consumption of chlorofluorocarbons by the end of the century. As the sole measure to limit ozone depletion, this may be insufficient, but it is a start in reducing the *pace* of change while we continue the detailed study of the problem on which our (the British) Stratospheric Ozone Review Group is about to report.

The third matter is *acid deposition* which has affected soils, lakes and trees downwind from industrial centres. Extensive action is being taken to cut down emission of sulphur and nitrogen oxides from power stations at great but necessary expense.

In studying the system of the Earth and its atmosphere we have no laboratory in which to carry out controlled experiments. We have to rely on observations of natural systems. We need to identify particular areas of research which will help to establish cause and effect. We need to consider in more detail the likely effect of change within precise timescales. And to consider the wider implications for policy — for energy production, for fuel efficiency, for reforestation. This is no small task, for the annual increase in atmospheric carbon dioxide is of the order of three billion tonnes. And half the carbon emitted since the Industrial Revolution remains in the atmosphere. We have an extensive research programme at our Meteorological Office and we provide one of the world's four centres for the study of climatic change. We must ensure that what we do is founded on good science to establish cause and effect.

In the past we have identified forms of pollution, we have shown our capacity to act effectively. The great London smogs are now only a nightmare of the past. We have cut airborne lead by 50 percent. We are spending £4 billion on cleansing the Mersey Basin alone; and the Thames now has the cleanest metropolitan estuary in the world. Even though this kind of action may cost a lot, I believe it to be money well and necessarily spent because the health of the economy and the health of our environment are totally dependent upon each other.

The Government espouses the concept of *sustainable* economic development. Stable prosperity can be achieved throughout the world provided the environment is nurtured and safeguarded.

Protecting this balance of nature is therefore one of the great challenges of the late Twentieth Century, and one in which I am sure your advice will be repeatedly sought.

Peroration

I have spoken about my own commitment to science and to the environment. And I have given you some idea of what government is doing. I hope that the Royal Society will generate increased popular interest in science by explaining the importance and excitement of your work. When Arthur Eddington presented his results to this Society in 1919, showing the bending

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Britain's Science Adviser Calls For More 'Practical' Science

For Britain's scientists, these are not the best of times. Many leaders of the scientific community are at loggerheads with the government, which pays for most of the research conducted in the country. The obvious cause of concern is money. A shortage of funds has held back salaries and efforts to upgrade equipment. What's more, the government is now funding a smaller percentage of the grant proposals it receives, even for top-rated research projects.

But behind the obvious concern over funding is another, deeper worry: that science will suffer because of a trend in governmental support toward more goal-oriented research and away from the basic or, as the British say, "curiosity" research that the scientific community traditionally espouses.

This shift began before John Fairclough took over as the Thatcher government's chief science adviser two years ago. But the 57-year-old Fairclough, an engineer by training who had spent most of his career at IBM, consciously accelerated the trend. At IBM, Fairclough had risen to become director of manufacturing in the UK because of his ability to turn ideas into products. And as the nation's science adviser, he is committed to bringing industry together with academia in order to make British science more "practical". One of his initiatives, the "Link" programme, for example, offers government funds for industry-university collaborations. Such efforts, he hopes, will reverse the century-old failure of UK companies to use the often brilliant inventions or discoveries of the nation's scientists.

But although no one quarrels with Fairclough's goal of finding commercial spin-offs for university research, many scientists fear that the science adviser's schemes may take away their cherished freedom.

Scientists also worry that worse measures are to come. And indeed, Fairclough admits that there are a number of further initiatives currently being considered by the government to foster the commercialization of science, although he insists that these will not adversely affect scientists. In this interview for The Scientist, *John Stansell, innovation editor of the* Sunday Times, *asked Fairclough to explain the government's push to change the nature of British science.*

Q Over the past few years, scientists have become increasingly critical about the levels — and direction — of government funding of science. Why are you continuing these policies in the face of growing protest?

A First of all, you are referring to university science and the concern that this community is expressing. You realize that my interests are far broader than just university science. Science in Britain must begin to target its efforts. Our country spends something less than 5% of the total cost of research done in the world, and we cannot expect to excel in everything. What that means is that we have to be selective.

We do need to sustain curiosity science at an appropriate level; history shows that science doesn't yield to prediction. But we also need to increase the amount of strategic science — science that is done for reasons of exploitability, although it is still basic science. The difficulty comes in determining which research has the greatest potential for exploitability.

Often, the judgement is reached with very little hard evidence. For example, one of the current discussions is over sequencing of the human genome. It is basic research. But there is a growing belief that a more detailed understanding of the human genome will lead to potential areas of exploitability, not only for commerce but also for quality of life. So should the human genome be labeled as strategic science so that we support it with more money? The only way of making these decisions is to create an environment in which both the academic and business communities decide to work together.

Q What would that environment be like?

A One of the challenges that we

are facing is trying to understand what the right arrangement would be. We want to provide leadership that is not too prescriptive but does give the right messages, and harnesses the ideas with the right quality. What is important is the quality of the ideas and the relationship between academics and the people who are willing to put up the money.

Q So what you are trying to do is to rethink the way that you manage the relationship between curiosity and strategic science?

A Yes, we are trying to identify those areas of curiosity science that have exploitation potential. And the only way of making that work is to have a partnership between the discoverer and the exploiter. Government can pick broad areas, but it surely can't pick projects. The key question is finding the proper dividing line between being prescriptive from the top and allowing good ideas to bubble up from the bottom.

Q What sort of mechanism can you set up both to find and to get the academic and industrial communities together?

A I have become a very active supporter of interdisciplinary research centres. I have been trying to focus on the boundary between the science and the exploiter, and on government's role in creating an environment that builds far greater interdependence across that boundary. It has to be done in a way that first protects the curiosity science — that's the seed corn — but which then creates an environment where academics come together into what I call goal-oriented research. It is necessary to bring several disciplines together because discoveries are occurring across the boundaries between traditional subjects.

Take the warm superconductors, for example. We did not discover them in Britain but we have started an interdisciplinary research centre at the Cavendish Laboratory in Cambridge that brings together a team of material scientists, physicists, chemists and engineers who can begin to fabricate these materials and experiment with artifacts. We do not yet know why the materials work, but we stand as good a chance as any of understanding that science. And he who understands the science is taking the first step toward making commercial products.

Q How are scientists reacting to these research centres?

A The centres represent focused target-oriented research. That is a bit of a culture change to the universities. Doing research on a team basis is something that universities are not used to. It cuts across their traditional boundaries. In addition, the true meaning of goal-oriented research is that you have a clear view of what you are trying to achieve and that the effect will be closed if you don't succeed. This comes as something of a shock to most university scientists.

Q How will the centres help industry get involved?

A It is the sort of environment that industry will identify with and will find a more attractive proposition. Now, I am not asking industry to put money on the table, at least not initially. But what I would like to see is industry putting people onto the research centre teams. Technology transfer begins with people. To invent the better mousetrap, we must stimulate more goal-oriented research.

Q But scientists worry that such research will mean reductions in the funding of curiosity work. Isn't that worry justified?

A I am in favour of finding ways of increasing the overall finances for universities, but not so they can do more of the same work they've been allowed to do in the past. We have 50-plus universities, and we cannot possibly afford to do world class science in every subject in every one of those universities.

Q So a few squeals of pain are entirely predictable?

A The scientists' fears are groundless. The scientific community is deeply worried that government is going to be highly prescriptive. It won't work that way. But what we must see is more interdisciplinary work rather than what I call the "stand-alone institution" where brilliant scientists work in ignorance of the real work.

That is already happening to some extent, but what I want to see is more of it. I also want to see more of the rights to the work being done owned by the universities. When we do manage to release more funds, they will be diverted into the campuses that have taken on board the importance of combining the goal-oriented work that I wish to see with their curiosity science.

Q So what do you feel about recent critical statements from men such as Sir George Porter, president of the Royal Society, expressing concern about the continuation of curiosity science?

A George Porter's interest, with which I have great empathy, is to ensure that we retain a proper level of curiosity science, particularly for awards to the young folk. He has got a point. We must protect that. But I compare the sort of speeches that Sir George has made with those made by Frank Press, president of the National Academy of Sciences. Press takes a much broader view. He analyzed recently, for example, the relationship that we've been talking about between goal-oriented and basic research. He noted that it is indicative of our times that industrial scientists have won Nobel Prizes. We must be willing, Press said in a speech this April, for the first time to propose priorities across scientific fields if the times call for it. And he is talking about a public science budget of $62 billion this year, compared with that in the UK of around $8 billion!

Q You say that you want to provide more funding for universities. Where might that money come from?

A I have been working very hard to persuade government to identify government-funded activities in industry that are near market, and to stop supporting those activities. The money then could be redirected toward strategic science. And that is all I am going to say about money.

Q How would you like to be remembered? As the man who made Britain able to exploit its science, perhaps?

A Ah, that might be going too far. But in whatever way I can, I aim to have a positive influence so that we can one day reach that objective.

■ Courtesy: *The Scientist*, 8 August 1988

The Art of Planning and Managing a Research Laboratory

Max Perutz shared the 1962 Nobel Prize in chemistry with John Kendrew for developing the X-ray diffraction techniques that revealed the structures of macro-molecules and, thereby, launched the science of molecular biology. But more recently, he has been lauded for his spectacular success as a manager of scientists. In particular, the accolades single out his tenure as head of the Medical Research Council's molecular biology laboratory in Cambridge, from 1947 to 1979. What makes a good manager? The Scientist *asked Perutz for his opinion.*

In 1959, when the Unit for Molecular Biology was still part of the Cavendish Laboratory, our budding fame brought a Soviet delegation to discover how I had planned the unit. Had I selected staff as Noah gathered animals for his Ark — two mathematicians, two physicists, two biochemists, and two biologists — and waited for their discoveries to hatch? Our visitors did not believe me when I said that we had grown naturally, like a tree.

Planning and managing a basic research laboratory is very different from running one for applied research, let alone a business. In applied research there is often a clear objective to be reached by directed team-work, while in basic research you are exploring unknown territory. Such a laboratory cannot be created at the stroke of a pen. It must evolve, attracting talented people who will be given a free hand. The director's most important task is not to lay down the law, but to listen to young colleagues, discuss their work, make them feel it is worthwhile, and help them to get the facilities they need.

Losing Touch

The director and senior scientists should be in the laboratory most of the time, and carry out their own research; otherwise they lose touch. But this is now outmoded in many universities, where committees and paperwork are expected to take precedence. Some directors run laboratories as factories for their own publications and lecture tours, repeating stock lectures like a gramophone record in different places, often to the same people. One candidate for a Cambridge chair listed over 30 publications in one year, all carrying his name as co-author. I wonder whether *he,* let alone anyone else, had read them all.

Following the tradition established at Cambridge's Cavendish Laboratory, I put my name on papers only when I had contributed scientific work, not when I had merely suggested experiments, given advice, or helped in writing up the results. This made younger scientists feel that they worked for themselves, not the boss, and was a vital stimulus to originality. It did not harm my career.

In many laboratories I have visited, individuals or small groups work in isolation, since communication between them is discouraged. People lock their rooms when they go home, lest anyone find out what they are up to, and meet colleagues only in the elevator. In 1960, when our new Laboratory of Molecular Biology was being built, projected costs were exceeding the approved estimate. To economize, I asked the architects to omit locks from our doors. This paid off in more ways than one. During the late 1960's, political unrest at UK universities led students to break open directors' rooms and rifle locked files. As my room and files were always open, I had no trouble. Besides, open doors are symbolic of our laboratory's atmosphere and tradition. I distrust scientists who complain about others stealing their ideas — I have always had to force new ideas down people's throats.

I knew one US professor who got furious if he saw anyone reading in the library during the day when they ought to be at the bench. But in my opinion, many young scientists work too much and read and think too little. Some directors have tackled this problem by making people clock in at nine and out at five, thus ensuring that no one works longer than the official hours. But such controls are a mistake. Science is not a nine to five job; it is usually better to finish the task at hand, whatever the hours.

The benefits of trust rather than control were brought home to me when a labour union told the Medical Research Council's technical officers to strike. Ours refused, because they enjoyed their work.

Discussion thrives at mealtime. We have a roof canteen where people congregate for lunch and for coffee and tea breaks, and argue as long as they like. Because seminars often attract only those already connected with the subject, we concentrate them in one week at the beginning of the academic year. It's called Crick Week after Francis Crick, who suggested this way of getting everyone to know what was happening, and who was the seminar's life and soul before he left for California.

In many US laboratories, financial disincentives discourage collaboration because each group has its separate grants and budgets. Sharing may involve financial loss. We avoid this problem by having a single budget for the entire laboratory and controlling expenditure by individual groups only when necessary.

Some years ago I visited the famous biochemist Otto Warburg in Berlin. He told me indignantly that after a lecture a student had dared to contradict him. "In the old days, such a thing could not have happened," he said. "If it did, Richard Willstätter would have put him in his place with a frown." Our students are encouraged to contradict their elders because it makes the students think, and to use first names, because science knows no hierarchy. In the British Scientific Civil Service everyone carries a title, but the Medical Research Council's scientific staff is graded only according to salaries — which promotes informality. Moreover, salaries depend on scientific merit, not the size of research groups, and people can reach the highest grades even if they work alone.

Scientific Pilgrims

The best laboratories are nourished by streams of graduate and postdoctoral students who bring fresh ideas and new approaches to old problems — which is easier to achieve when linked to a good university. Our laboratory has a turnover of about 25% per year, and scientific pilgrims come from all over the world.

The desirable qualities of a laboratory chief are as hard to define as those of a good spouse. According to one psychologist's survey, men use their managerial jobs to bolster their masculinity and sublimate aggression, greed, and envy. Such personalities do not make the best leaders of research. The positive qualities needed are judged best from descriptions of great heads of laboratories of the past. Noted Russian physicist Peter Kapitsa once described how Ernest Rutherford ran the Cavendish Laboratory:

"England provided the most outstanding physicists, and I now begin to understand why: the English school develops individuality extremely widely and provides infinite room for the manifestation of the personality... [At Cavendish] they often do work which is so incredible in its conception that it would be simply ridiculed in Russia. The Crocodile [Kapitsa's nickname for Rutherford] values so highly that a person should express himself that he not only allows them to work on their themes but also encourages them and tries to put sense into these sometimes futile plans... It is not surprising that he is capable of making 30 people work." (From *Rutherford: Simple Genius,* by David Wilson, Hodder and Stoughton, 1983.)

British physicist Sir Nevill Mott wrote of Niels Bohr *(The Scientist,* October 15, 1986, page 15): " We were in and out of each other's rooms all day, and so was Bohr. Nobody dreamt of keeping an idea to himself; our joy in life was to tell it to other people to get it criticized and if possible accepted. Bohr himself, if he had a new idea, would ... tell it to the first person he could find ... I learned [from Bohr] what physics was all about, that it was a social activity and that a teacher should be with his students."

Most scientists are enthusiastic about their own ideas and discoveries, Rutherford and Bohr were exceptional in being enthusiastic about those of others. It was this generous spirit, the atmosphere of all things being possible, along with their scientific professionalism, intellectual force, and imaginative genius, rather than "management", that made their laboratories inspiring and successful places in which to work.

■ *Max Perutz was Chairman of the Medical Research Council Laboratory of Molecular Biology in Cambridge (UK), from 1962 to 1979, and still works there.*

Courtesy: *The Scientist,* 8 August 1988.

Cooperative Fusion Project Moves into Next Phase

High-level representatives of the European Community, Japan, the Soviet Union, and the United States have agreed on the basic technical description of an experimental facility that could provide proof of the science and technology of controlled thermonuclear fusion. The agreement was reached at the conclusion of a two-day meeting of the International Thermonuclear Experimental Reactor (ITER) Council hosted by the IAEA in Vienna on 1-2 November.

The technical description was the outcome of five months of intensive joint work by more than 200 scientists and engineers. A core group of 40 specialists worked in a fully integrated effort at a site provided by the European Community in Garching, Federal Republic of Germany. The envisioned machine is called the international thermonuclear experimental reactor (ITER). Project leaders say it could become operational around the year 2000 if a timely decision is made to construct it. The ultimate objective of fusion, a source of energy that experts say promises to play a large role in meeting the world's energy needs after this century, is to produce and sustain a "miniature sun", whose energy could be harnessed to produce electricity.

The first phase of ITER cooperation was to bring together technical experts form the major fusion programmes to work out a mutually acceptable "concept definition". At the outset, it was agreed to use the so-called "tokamak" configuration which was originally developed in the USSR. Since then, tokamaks have been built in increasing scale and sophistication and have operated experimentally in many countries. The ITER definition included choices of machine parameters and design concepts. Technical choices were tentatively made of magnets, materials, and maintenance arrangements. Finally, the definition included requirements for supporting research and development and an outline of a programme of experimental operation.

ITER activities are now progressing into the design phase. The final report on the ITER design is expected at the end of 1990. This would enable each government to decide how best to proceed in fusion development.

In announcing the ITER Council's approval of the concept definition, Council Chairman Dr. John Clarke said that the work "represents a major step toward the harnessing of fusion power." He emphasized that the "remarkable technical progress achieved in such a short period of time shows what can be accomplished when nations pool their scientific and engineering resources in pursuit of a worthwhile common objective."

■ *IAEA Newsbriefs,* 5 November 1988

Mrs.Thatcher's Address at the Royal Society — Cont'd from page 25

of starlight, it made headlines. It is reported that many people could not get into the meeting, so anxious were the crowds to find out whether the intellectual paradox of curved space had really been demonstrated. Should *we* be doing more to explain why we are looking for the Higgs boson at CERN and trying to decode the human genome? This is a golden era of discovery and new thought. The natural world is full of fascination, providing the doors of understanding are opened. I applaud our Royal Society for its manifold achievements and congratulate you, Mr. President, on your splendid leadership. I ask you to drink a toast to the Royal Society.

Greenhouse Effect 'Caused Dustbowl'

The "dustbowl" drought in America is "99 per cent certain" to be an early manifestation of climatic changes, caused by pollution, which scientists have predicted for years, a leading space agency specialist has told a congressional committee.

Dr. James Hansen said the evidence was that the "greenhouse effect"—expected to cause a rise in world temperatures and a series of droughts as infra-red rays from the sun are trapped in the atmosphere by carbon monoxide and other pollutants—had begun.

"It is time to stop waffling so much and say that the evidence is pretty strong that the greenhouse effect is here," said Dr. Hansen who monitors both global temperatures and the contents of the atmosphere for the National Aeronautics and Space Administration.

Until Dr. Hansen made his statement to the committee, scientists have been saying that this year's heat wave in America could simply be part of the natural cycle of climatic variation with the greenhouse effect still some years away.

Statistics compiled by NASA show, however, that the warming effect has gone beyond any previously logged variations. The expected results—drought, a drop in fresh water levels and an increase in the sea level as the ice-caps begin to melt-have already started.

"Global warming has reached a level such that we can ascribe with a high degree of confidence a cause and effect relationship between the greenhouse effect and observed warming," said Dr. Hansen.

The beginning of the greenhouse effect means, said Dr. Hansen, that the Midwest and southeastern areas of America can expect to be caught in a cycle of very high temperatures and frequent droughts for at least the next 10 years.

The effects of the climatic changes could, however, last for centuries, particularly if governments failed to curb pollution.

Mathematical models produced by scientists have given warning for some years that the build-up of gases in the atmosphere would alter the climate.

The models suggest that if the build-up continues, the world will increase its mean surface temperature by between three and nine degrees Fahrenheit from the years 2025 to 2050. The increase would be greatest at the poles and least at the equator.

Sea levels would rise by between one and four feet by the middle of the next century as the polar ice-caps melted and the oceans, their temperature increased, expanded. Lakes, rivers and underground reservoirs would shrink.

Scientists have already recorded a slight rise in sea levels and an increase in the average global temperature. Dr. Hansen said that the average temperature was one-third of a degree higher last year compared to a 30 year mean of 59 °F from 1950 to 1980. Global temperature had risen by half a degree, during the entire 100 years before 1980.

Dr. George Woodwell of the Woods Hole Research Centre in Woods Hole, Massachusetts, said that countries must make immediate plans to reduce the amount of fuel burnt if the greenhouse effect was to be minimized.

One obvious course of action was to stop the rapid deforestation of many parts of the world, followed by an energetic programme of tree planting, as trees absorb carbon dioxide.

Conservation and the adoption of the most efficient uses of energy from existing fuel sources would slow the phenomenon, but some scientists have started to argue that the evidence of the greenhouse effect taking grip would justify the revival of attempts to develop nuclear energy.

As the American drought continues to inflict widespread damage on crops, the Agriculture Department has predicted that food prices will rise by about one per cent.

Roger Highfield, Technology Correspondent, writes: The greenhouse effect is caused by a range of gases, most notably the carbon dioxide resulting from the combustion of fossil fuels, though methane and chlorofluorocarbons — used in aerosol sprays, refrigerators and plastic foams — are also important contributors to the effect.

In the greenhouse effect, visible light from the sun is absorbed by the earth and the atmosphere. The earth warms and radiates the heat at longer wavelengths back to space. However, gases in the atmosphere trap the heat in a similar manner to the glass in a greenhouse.

An initiative to curb man's influence on the climate was expected to be launched at a conference in Toronto, one of the organisers, Dr. Henry Hengeveld of Environment Canada, has revealed.

He said representatives of governments, including Britain, legal experts, economists and industry will be told by scientists the effects of man on the climate, notably the ozone hole, acid rain and the greenhouse effect.

"One of the byproducts we expect at the World Conference on The Changing Atmosphere will be the initiation of development of a 'Law of the Atmosphere'."

Dr. Hengeveld said he was unwilling to link the dustbowl drought to the greenhouse effect. He added: "We should certainly start getting concerned about the greenhouse effect, but whether it is here, I don't think I would go as far as Dr. Hansen."

■ Charles Laurence (Courtesy: *The Daily Telegraph,* 25 June 1988)

Suggestions and Comments are Welcome

Would you like to express your opinion in the TWAS Newsletter? Do you wish to make a suggestion? Or do you have any comments? Please write to us and let us know!

Scintillating Days With Rutherford

E.T.S. Walton and John Cockcroft made history in the early 1930's by bombarding atomic nuclei with accelerated protons and "splitting the atom." But experimental physics was a low-tech, low-budget enterprise, then compared to today. "We had to make various parts of our apparatus," Walton recalled in a recent interview with The Scientist's Bernard Dixon. "But before requesting the necessary materials, everyone was expected to see if items salvaged from unwanted apparatus could be used. I wasted lots of time searching for suitable screws in a large box of rusty ones."

Now aged 84, Irishman Walton still drives over from his home in Dublin for seminars at Trinity College, from which he retired as Erasmus Smith's Professor of Natural and Experimental Philosophy 14 years ago. He is principally famed for his work on the structure of the atom, for which he shared the 1951 Nobel Prize with Cockcroft. But Walton's eclectic career also includes important work in fields as diverse as microwaves and hydrodynamics.

Here he describes his exciting early days in Ernest Rutherford's laboratory.

After graduating in physics and mathematics at Dublin's Trinity College in 1926, it was natural that I should want to go to the University of Cambridge, England, which was noted for its preeminence in both of these subjects. Ernest Rutherford was director of the Cavendish Laboratory at Cambridge and the world leader in studying radioactivity, which had been discovered in 1896. Physicists from many other countries were anxious to do research under him, but lack of space and facilities limited the number of research students to about 50. In 1927, I became one of the fortunate few.

Considering his momentous achievements — especially his discovery of the nuclear structure of atoms and the transmutation of elements — Rutherford was surprisingly modest. He used to say that, being a simple person, he believed all basic ideas in physics would prove to be simple too. Most of Rutherford's research was conducted with very simple apparatus — I suspect that he believed more time would be spent keeping complicated equipment in working order than in getting results.

A Reasonable Man

Rutherford was also very reasonable in his dealings with research students. He did not expect one to be a genius. Realizing that students would be nervous during the Ph.D. oral, he used to begin with some easy questions. On one occasion, a fellow examiner asked an atrocious question, which had the candidate struggling. Rutherford interrupted, "It is obvious that the student cannot answer that question," he said. "I cannot answer it myself. Please tell us your answer." The hapless examiner had to admit that he couldn't do so.

Rutherford's fellow-feeling for students may have come from his own sporadic lapses in completing mathematical calculations when lecturing. On one occasion, he tried to calculate the radius of an electron using classical theory, but failed. He told the class to work it out for themselves, and added they should not worry unduly because the result was not particularly meaningful anyway.

Of course, Rutherford had his faults. He was very jealous of his position as director of the Cavendish, and it was extremely unwise for any research student to suggest ways in which the place could be better run. He was criticized, especially by the assistant director, James Chadwick (discoverer of the neutron), for not throwing his weight around to secure more financial support. The laboratory was certainly poverty-stricken. Simple instruments like ammeters and voltmeters were in short supply. And some research students even had to spend their own money on apparatus they could ill afford.

Additional Finance

Sir Hugh Anderson, master of Caius College, Cambridge, knew that additional finance was badly needed but could not be provided by the university. So he persuaded some wealthy friends to give £2,000 per annum over several years. That was a lot of money in those days. Yet without consulting anyone, Rutherford decided to have nothing to do with this generous offer. Chadwick thought that Rutherford was afraid he might have to write long reports, and that he would not be able to justify such a large expenditure.

Soon after I arrived at the Cavendish, Rutherford summoned me to discuss a line of research. He knew that if he decided on a problem that really interested a student, he would get much better work. So he asked whether I had any ideas.

I suggested a method of generating fast electrons by keeping them in a circle that was a line of an electric field (as in a modern betatron). This was lucky, because unknown to me, in his annual address as president of the Royal Society a few weeks earlier, Rutherford had pointed out the need to develop ways of producing fast particles. He was probably pleased to find a student interested in going into this difficult field. Rutherford proposed a modification, and I went ahead. But all of my experiments failed, because at that time no one knew how to keep electrons on a circular orbit.

My second suggestion was the method of the linear accelerator, in which high-frequency voltage is applied to a series of hollow cylindrical electrodes. While I was trying to get the method to work, toward the end of the 1920s, two papers appeared, one by George Gamow in Leningrad and the other by Edward Conon and R.W. Gurney in Princeton. Both applied the new wave mechanics to the problem of the emission of alpha particles from radioactive substances. Gamow subsequently lectured on this in Cambridge, and during a conversation with John Cockcroft, they realized that the same theory could be used to calculate the probability of getting fast particles into the nuclei of atoms.

Cockcroft pointed out to Rutherford that the new theory predicted that the protons, accelerated by a few hundred thousand volts, had a significant chance of getting into the nuclei of light atoms such as lithium. Until that time, we all believed that millions of volts would be required. So it was decided that Cockcroft and I should build equipment to produce protons accelerated by up to 300,000 volts.

Initially we adopted vacuum tubes like those made to produce X-rays. But these would not stand up to the high voltages we wanted. Straight cylinders proved much better. Our first ones came from an unusual source: the measurement mechanism in gasoline pumps. We were able to obtain larger tubes later because the making of glass cylinders was a stage in one process for manufacturing sheet glass. Four of these cylinders could be stacked into a column 12 feet high, giving us four rectifiers evacuated by one pump — an important saving.

On April 4, 1932, we placed a lithium target and a fluorescent screen at the bottom of the tube in which protons were to be accelerated. We then focused a microscope on the screen in the hope of seeing some scintillations, which would indicate that a nuclear reaction had occurred. The introduction of the target and screen necessitated letting air into the apparatus. Due to the high voltage and high vacuum, more than an hour was needed to get the apparatus working properly again. As this could be done by one person, John Cockcroft left to give some help to Petr Kapitza in the Magnetic Laboratory.

On completing the conditioning, I left the control table and looked through the microscope. To my delight, there were scintillations, which appeared like those I had read about in books on alpha particles. After carrying out various checks to make sure that I was not imagining things, I called Cockcroft. He came over at once, and he too satisfied himself that the scintillations were genuine. Rutherford was then informed, and he joined us immediately. Few things pleased him more than seeing a worker get results. In our case, he was especially interested because of his great love of alpha particles.

Rutherford was a big man, but we managed to manoeuvre him into the little hut we had built under the accelerating tube to protect us from the X-rays. He peered into the microscope and gave instructions about varying the voltage and proton current, but made no comment on what he saw. Finally, he told us to switch everything off.

"Those scintillations look mighty like alpha-particles ones," were his first words. "I should recognize an alpha-particle scintillation when I see one. I was in at the birth of alpha particles and have been observing them ever since." Indeed, Rutherford was present at their christening too, for it was he who gave them their name. He had also used them as tools in his two greatest discoveries — the nuclear structure of atoms and the transmutation of nitrogen into oxygen.

Rutherford returned the next day and did some counting of the alpha particles. He insisted that no one be told about our success. If the results became known, he said, a lot of people would want to see the apparatus, and we would get no work done. Over the next four days, this wise precaution enabled us to amass a lot of information about the disintegrations and even to observe the particle tracks in a Wilson cloud chamber.

A few weeks later, Rutherford reported our results at a meeting of the Royal Society in London. The announcement was given headlines in newspapers all over the world. In part, this was because of a play then running in London, the plot of which involved a scientist who had discovered how to split atoms. The power that this gave the fictional scientist enabled him to hold governments at ransom.

■ E.T.S.Walton (Courtesy: *The Scientist*, 30 May 1988)

The Four Most Cited Papers — Cont'd from page 21

tive method for the quantitation of microgram quantities of protein utilizing the principle of protein dye-binding" in *Analytical Biochemistry*, **72**, 248-54. Many now cite the Bradford paper instead of the Lowry paper — more and more all the time. With about 20,000 citations by the end of last year, the Bradford paper is now the fourth most cited paper in the *SCI*.

The runner-up to Lowry, written by Ulrich Karl Laemmli, was published in *Nature*, **227**, 680-5. "Cleavage of structural proteins during the assembly of the head of bacteriophage T4" accumulated nearly 50,000 citations between its publication in 1970 and the end of 1987. The procedure has not been superseded, which explains its steady rise in the chart.

The third most cited article, with just over 20,000 citations is "Reliability of molecular weight determinations by dodecyl sulfate-polyacrylamide gel electrophoresis," by K. Weber and M. Osborn, published in 1969 in the *Journal of Biological Chemistry*, **244**, 4406-12. The record of citations to this article shows a more typical pattern for well-known and highly cited papers — the "obliteration by incorporation" effect, whereby the substance of a work becomes so widely recognized that overt citation is eventually deemed unnecessary. Such seems to have been the fate of this classic since 1977.

■ David Pendlebury (Courtesy: *The Scientist*, 8 August 1988)

Why Scientists Should Start Playing the Political Game — cont'd from page 22

bers of Congress, staff members, and federal officials are invited to hear distinguished behavioural scientists describe research that bears directly on public issues.These seminars offer a valuable opportunity to meet and influence legislators, but the community as a whole needs to do more. Its diverse professional societies should work together to develop a public relations effort to make their areas of research more visible to the public and Congress.

Individual scientists can also contribute by introducing themselves and their work to their own congressional representatives and staff. In addition, the research community would do well to track research appropriations in each of the several agencies that fund its research, and to establish relationships with the appropriate congressional committees and staff.

Reversing the decline in the research budget for any discipline requires political savvy, and the social and behavioural science community needs to become more adept at playing the game.

■ R.K. Dismuskes (Courtesy: *The Scientist*, 8 August 1988)

The Third World Academy of Sciences

1989 History of Science Prize

In 1987 the Third World Academy of Sciences instituted a Prize for the best research essay highlighting the work of a scientist from a country of the Third World whose achievements had not been previously recognized.

The first of these prizes was awarded in October 1988, for an essay on some remarkable astronomical tables which were used in Damascus from the fourteenth century to the nineteenth, compiled by a computational genius Shams-al-Din al-Khalili. Some of these tables, providing numerical solutions to the cosine formula of spherical trigonometry, were unparallelled in later centuries until the early modern period.

As a result of the enthusiastic response to the announcement of the first prize and the success of that first competition, the Third World Academy of Sciences is pleased to invite submission of essays to be considered for a Second History of Science Prize to be awarded in 1990.

The regulations, similar to those pertaining to the award of the first prize, are as follows:

- The essay should summarize the major achievements of a Third World Scientist. It should indicate the impact of the scientist's contributions on his/her community and, where relevant, establish their influence on modern scientific thought.
- Essays on previously unstudied works by scholars who are already known to the modern literature will also be considered.
- Essays on themes in the history of science which are not associated with one particular scientist or individual will also be considered.
- Essays must be written in the English language.
- The length of the essay should be between about 20,000 and 50,000 words, but these limits are not binding.
- The competition is open to scholars both from the Third World and elsewhere.
- Essays should be received by the Executive Secretary of the Third World Academy of Sciences no later than 28 February 1990 at the address given below.
- All essays satisfying the above conditions will be judged by an International Committee of experts in the History of Science appointed by the Third World Academy of Sciences.
- The 1989 Prize will consist of a medal and US$ 10,000. It will be awarded at the Academy in the Autumn of 1990.
- The Third World Academy of Sciences will arrange for the prize winning essay to be published in book form.
- The Committee may advise authors of other essays deemed to be of exceptional merit in what form their work could be published elsewhere. The Committee may advise authors of essays deemed to be of exceptional promise how they could improve their essays and prepare them for eventual publication. The Academy is not obliged to offer such advice.

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