NOTES ON SCIENCE, TECHNOLOGY AND SCIENCE EDUCATION IN THE DEVELOPMENT OF THE SOUTH

Abdus Salam

(Prepared for the 5th and 6th Meetings of the South Commission,
27-30 May 1989, Maputo, Mozambique
and 11-14 November 1989, New Delhi)

THE THIRD WORLD ACADEMY OF SCIENCES

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(SECOND EDITION)

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ABSTRACT

This globe of ours is inhabited by two distinct types of humans. According to the UNDP count of 1983, one quarter of mankind, some 1.1 billion people are developed. They inhabit 2/5ths of land area of the earth and control 80% of the world's natural resources, while 3.6 billion developing humans - "Les Misérables" - the "mustazeffin" (the deprived ones) - live on the remaining 3/5ths of the globe. What distinguishes one type of human from the other is the ambition, the power, the élan which basically stems from their differing mastery and utilisation of present day Science and Technology. It is a political decision on the part of those (principally from the South) who decide on the destiny of developing humanity if they will take steps to let Les Misérables create, master and utilise modern Science and Technology. These notes are devoted to this topic.

"In the conditions of modern life, the rule is absolute: the race which does not value trained intelligence is doomed ... Today we maintain ourselves, tomorrow science will have moved over yet one more step and there will be no appeal from the judgement which will be pronounced ... on the uneducated".

Alfred North Whitehead

THE TRIESTE DECLARATION

on Science and Technology as an Instrument of Development in the South*

"Recognising the fundamental importance of Science in socio-economic and cultural development and technological progress, and keeping in view the recommendations of the South Commission pertaining to the crucial role of Science in the Third World, as mankind approaches the 21st century, the members of the Third World Network of Scientific Organisations present at the meeting held in Trieste from 4-6 October 1988, resolve to work towards giving Science and Technology a position of highest priority in their own countries and to strengthen their collaboration with other countries of the South as well as of the North".

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* There were 15 Ministers of Science and Technology, 12 Presidents of Academies and 17 Chairpersons of National Research Councils, representing 36 Third World countries, present at the inaugural meeting of the Third World Network of Scientific Organisations (TWNSO) when this declaration was adopted.

1. SCIENCE AND TECHNOLOGY, A SHARED HERITAGE OF MANKIND

The first thing to realise about the Science and Technology gap between the South and the North is that it is of relatively recent origin. In respect of sciences, George Sarton, in his monumental History of Science, chose to divide his story of achievement into Ages, each Age lasting half a century. With each half-century he associated one central figure. Thus 450-400 BC Sarton calls the Age of Plato; this is followed by the half-century of Aristotle, of Euclid, of Archimedes and so on. These were scientists from the Greek Commonwealth consisting (in addition to the Greeks) of Egyptians, Southern Italians and ancestors of modern Syrians and Turks.

From 600 AD to 650 AD in Sarton's recount is the Chinese half-century of Hsüan Tsang. From 650 to 700 AD is the age of I-Ching (and of the Indian mathematician, Brahmagupta), followed by the Ages of Jabir, Khwarizmi, Razi, Masudi, Wafa, Biruni (and Avicenna), and then Omar Khayam - Chinese, Hindus, Arabs, Persians, Turks and Afghans - an unbroken Third World succession for 500 years. After the year 1100 the first Western names begin to appear; Gerard of Cremona, Roger Bacon and others - but the honours are still shared for another 250 years with the Third World men of science like Ibn-Rushd (Averroes), Tusi and Sultan Ulugh Beg.

The same story repeats itself in Technology in China and in the Middle East, at least till around 1450 when the Turks captured Constantinople because of their mastery of superior cannonade. No Sarton has yet chronicled the history of medical and technological creativity in Africa - for example of early iron-smelting in Central Africa 2500 years ago. (Scientific American, June 1988 issue). Nor of the pre-Spanish Mayas and Aztecs - with their independent invention of the zero and of the calendars, of the moon and Venus, as well as of their diverse pharmacological discoveries, including quinine. But one may be sure, it is a story of fair achievement in Technology and Science.

From around 1450, however, the Third World begins to lose out (except for the occasional flash of individual brilliant scientific work), principally because of the lack of tolerant attitudes to the creation of Sciences. And that brings us to the present century when the cycle begun by Michael the Scot who went from his native glens in Scotland, South to Toledo and then to Sicily (around the year 1220 A.D.), in order to acquire knowledge of the works of Razi, Avicenna (and even of Aristotle) turns full cycle - and it is we in the developing world who must turn Northwards for Sciences.

Science and Technology are cyclical. They are a shared heritage of all mankind. East and West, South and North have all equally participated in their creation in the past as, we hope, they will in the future - the joint endeavour in Sciences becoming one of the unifying forces among the diverse peoples on this globe.

2. THE WIDENING GAP IN SCIENCE AND TECHNOLOGY

Today, the Third World is only slowly waking up to the realisation that in the final analysis, creation, mastery and utilisation of modern Science and Technology is basically what distinguishes the South from the North.* On Science and Technology depend the standards of living of a nation. The widening gap in Economics and Influence between the nations of the South and the North is essentially the Science and Technology gap. Nothing else - neither differing systems of economics nor of governance, nor differing cultural mores, nor differing perceptions of religious thought, - can explain why the North (to the exclusion of the South) can master** this globe of

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* The economist will no doubt supplement this with other - and what I believe are secondary - factors which affect overall development, for example: a) lack of political stability in the South; b) population pressures; c) unequal opportunity in the societies in the South; d) climate. (South-North differences may be adduced within the context of the individual societies in the North. For example, Southern England is more prosperous than the North; Northern Italy is more prosperous than the South. Such differences, (attributed presently to climate and historically unimportant motivational patterns), do not affect the general thrust of the arguments in the text).

These notes are addressed to overall development and are not concerned with the social scientist's legitimate worries about any lop-sided distribution of wealth generated within a given Southern society.

** One aspect of the South's deprivation in Sciences is the fact that Science (even as contrasted with Technology) has been treated as a marginal activity by the South. (The words "Science" or "Science Transfer", for example, do not occur in the Brandt Commission Report). Very few within the developing world appear to realise that the science of today is the technology of tomorrow.

ours and beyond. Why does this gap exist and why is it growing so fast?*
Why is the size of Science and Technology sub-critical and their utilisation in the South so meagre?

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* The role of superior technology in the rise and fall of nations is a relatively neglected subject. Thus, for example, when we think of the British conquest of India, the part played by the superior fire power of Clive's British-made arms is forgotten. It is equally forgotten that the British "trained themselves" to manufacture such arms. Nor is the role played by the navigational skills (developed at the secret Centre in Sagres in Portugal through the personal interest of Prince Henry the Navigator) - which permitted European ships to sail straight into the oceans, rather than hug the coast lines - ever taken into account. Why men like Prince Henry the Navigator arise from time to time among some peoples is, of course, one of Nature's mysteries.

I shall endeavour to answer these questions in this report. But before I do this, let us start with two remarks. One concerns the long-term nature of Science and Technology as applied to development. We are not likely to see the benefits for a long time. The year 2000 would be a good year to aim at if we start today.

My second remark concerns the widespread feeling that the acquiring of Science and Science-based High Technology is hard. I would like to say emphatically that this is not the case. In eloquent phrases, C.P. Snow, in his famous lecture on "The Two cultures", made the point that Science and Technology are the branches of human experience "that people can learn with predictable results ... For a long time, the West misjudged this very badly. After all, a good many Englishmen have been skilled in mechanical crafts for half-a-dozen generations. Somehow, we, in the North, have made ourselves believe that the whole of technology was a more or less incommunicable art."

In Snow's words: "... There is no evidence that any country or race is better than any other in scientific teachability*: there is a good deal of evidence that all are much alike. Tradition and technical background seem to count for surprisingly little.

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* "Britain offers the best combination of low labour costs (the lowest in industrial Europe except Spain) and relevant skills. Spanish workers are thought to be less skilled ... than British ones. That is not much of a benchmark: by and large British skills are "relevant" because the country's workforce is less well-educated and less well-trained than that in France or West Germany, for instance. In other words, at present wage levels, Britons are better suited to fairly humdrum tasks - like assembling Japanese cars. ...

"This is not a reason to keep the Japanese out, but rather a reason to upgrade education and training (in the UK). Western firms have talked for years about learning from Japan, but it is easy not to do your homework when the teacher is 5,000 miles away". (Business in Britain Survey, *The Economist*, 20 May 1989, p. 19).

"There is no getting away from it. It is ... possible to carry out the scientific revolution in India, Africa, South-East Asia, Latin America, the Middle East, within fifty years. There is no excuse for Western man not to know this". *

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"Technology is a gift of God. After the gift of life it is perhaps the greatest of God's gifts. ...

"The most revolutionary aspect of technology is its mobility. Anybody can learn it. It jumps easily over barriers of race and language. It took three generations of misery for the older industrial countries to master the technology of coal and iron. The new industrial countries of East Asia, South Korea and Singapore and Taiwan, mastered the new technology and made the jump from poverty to wealth in a single generation.

"... If we are to lead the world toward a hopeful future, we must understand that technology is a part of the planetary environment, to be shared like air and water with the rest of mankind. To try to monopolize technology is as stupid as trying to monopolize air. ...

"Unlike our political leaders, we have first-hand knowledge of a business which is not merely multinational but in its nature international. ... As scientists we work every day in an international community. ... That is why we are appalled by the narrow-mindedness and ignorance of our political leaders. ..." - Freeman Dyson. (Appendix X).

3. THE FOUR AREAS OF SCIENCE AND TECHNOLOGY

Civilian Science and Technology may perhaps be divided into four categories of 1) Basic Sciences; 2) Sciences in Application; 3) Conventional "Low" Technology; and 4) Science-based "High" Technology.

Let us consider each of these areas in turn.

A) Basic (curiosity-oriented*) Sciences.

There are at present five sub-disciplines comprised among these:

(1) Physics (including Geophysics and Astrophysics); (2) Chemistry; (3) Mathematics; (4) Biology; plus (5) Basic Medical Sciences.

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* The curiosity-orientation of Basic Sciences has been beautifully expressed by David Hilbert, the great Goettingen mathematician (who lived in the early part of the 20th century). This was brought to my attention by Dr. Wolfgang Wild, the Minister of Science of the State of Bavaria, who had the following to say: "The medieval society has invested a much greater part of its social product in the building of cathedrals than we are investing in fundamental research. The increase in our knowledge of truth is a goal which has a dignity no less than the building of cathedrals. There is good reason for the opinion that the most important cultural contribution of our epoch to the history of mankind is the progress of scientific knowledge whereas the building of cathedrals can be considered as the most important contribution of the Middle Ages. Therefore it is my firm conviction that we should join the confession of the great mathematician David Hilbert who wanted to have the following inscription on his tombstone: 'WE MUST KNOW. WE SHALL KNOW' ".

The present has been called the greatest century of Basic Sciences because there have been absolutely fundamental advances (like "quantum theory, curved space-time") in the first part of the century and Standard Models elaborated in Particle Physics, in Astrophysics (Big Bang Model), in Earth Sciences (Plate Tectonics) and in Biology (Double Helix Model) during the second half. The tasks of future generations of researchers from the Third World to improve on these will, we are afraid, be that much harder.

Research and training for Basic Sciences is conducted in the Universities or in the Research Centres specifically created for this purpose in the North. As a rule, these are funded by National Science Foundations or by Academies of Sciences (which are also responsible for international contacts of scientists).*

So far as developing countries are concerned, by and large we have tended to neglect this area of Science assuming, for some reason that we could live off the scientific results obtained by others. This has been an unmitigated disaster in that it has also deprived us of men and women who would know about the basics of their disciplines,** who could act as

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* To obviate the problems of Research unconnected with teaching, the best modality has been invented in the US where all scientific research, whether for Basic or Applied purposes, is conducted either in the universities directly, or in institutes which may be federally financed but are almost always linked with the universities. For example, the major laboratories of the US Department of Energy - the Brookhaven National, the Argonne National and the Los Alamos Laboratories - all are operated on behalf of the Department of Energy - by consortia of universities.

** I am not recommending here the setting up in the Third World of the likes of the 200 inch telescope at Mount Palomar (which was a gift from the Rockefeller Foundation), nor the setting up of the great (but costly) laboratories like CERN in Geneva for Particle Physics financed by a consortium of European nations. (However, one project of relatively Big Science has much to recommend it. This is the project for an equatorial radio telescope to be built by African and Arab countries with Indian help. This project will not be financed by any of the Western countries and is not all that costly).

However, I definitely do believe that a profound knowledge of the basics is absolutely vital for applications and that research is a sine qua non for assuring such profound knowledge. Nothing can give that instinct of what is credible and what is not, that fine sense of the scientifically genuine and the scientifically deceptive, as the direct experience of living science - living in one's own conditions and environment and flourishing within one's own cultural tradition.

references to whom one could turn, to discuss the inevitable scientific problems which arise when applications of Science are made.***

***

As Professor Jean-Patrick Connerade of Imperial College, London, has remarked: "In our culture, the enthusiasm (for Science and Technology) is fired by supporting basic research. Successful university laboratories are essential to attract the best young brains into a scientific career. Whether they remain in research or opt for development is up to them to decide. ... This is one of the hidden benefits of fundamental research. Its glamour has inspired many scientific careers which did not end up in the (basic) research laboratory".

The difference between the North and the South is that whereas it is perfectly possible to change over from basic to applied research in the North, it is seldom possible in the South for lack of opportunity. Thus, many in the South have felt resigned to carry on as best as they can, with the basic scientific disciplines in which they were brought up and which may have passed them by.

This is one of the features which the International Centre for Theoretical Physics at Trieste, has tried to correct. In many instances, those from the South (brought up in basic disciplines) have been encouraged to migrate to applied research.

B) **Sciences in Application.**

One may list five areas of Sciences in Application: These are (1) Agriculture (including Livestock, Fisheries and Forests); (2) Medicine and Health; (3) Energy; (4) Environment and Pollution; (5) Earth Sciences (including Irrigation and Soils, Meteorology and Oceanography, Minerals Exploitation, as well as Seismology).

As a general rule, Research and Development in Applied Sciences are carried out in the North under the auspices of Research Councils or by private industry.* This includes Research, Development (Adaptation and Modification) and Application of Scientific Methodology to developmental problems.** The Research effort, in order to be effective, must be supplemented with first-class extension services.***

What is emphasised more in any given country depends on a nation's priorities and can not be spelt out here.

An essential part of the research and development process is the availability of scientific literature.

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* Inspite of the large technological content of some of these areas, it is important to realise that these are not areas of technology, but of science. Different societies have differing problems and sub-areas which naturally need emphasising more than others but almost all societies would need to emphasise agriculture and the local materials- base as legitimate priority areas of Sciences in Application.

** I must once again emphasise the importance of harnessing Applied Scientists for economic growth and for the betterment of the human condition - be it in improving agricultural output, medical advances, local materials or efficient transportation and housing. (This is done under the name of "Scientific Humanism" in the North although as a rule such "Scientific Humanism" is not concerned with the plight of the South). It is also important for the economist to realise that Applied Science is not always the same thing as Technology (which is a term reserved for manufacturing).

*** Such extension and "one-window services" are important ingredients of the type of political input which we have spoken about in the Abstract of this paper. Scientists themselves must play a role in ensuring that extension services do exist and their research does not go waste. (This is the additional cross which must be carried by the Applied Scientist in a developing country).

It is important to realise that the distinction between Basic and Applied Sciences on the one hand and Applied Sciences and Technology on the other is not absolute.* There inevitably are gradations.

TECHNOLOGY**

C) **Classical "Low" Technology.**

The five sub-areas of this are:

(1) Bulk Chemicals; (2) Iron and Steel and Other Metals Fabrication; (3) Design and Fabrication in (indigenous) Industries (like Cotton and Leather); (4) Petroleum Technologies; (5) Power Generation and Transmission plus Heavy Electrical Industry.

Here no new scientific principles remain to be discovered. However, Developmental work relating to design, adaptation and modification, is important. This is the traditional area of craftsmanship and skills - the science employed is of yesteryears. Thoroughness (in all aspects in the manufacture and after-services), beauty of design, the quality of workmanship, cost, and manufacturing-competitiveness are all-important. These are just the areas where developing countries should NOT be deficient.

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* "It is generally impossible to predict within the timescale of scientific advance what research is pure and what is applied. Sir George Porter phrased this beautifully in stating that there are only two kinds of science: 'applied and not yet applied'. All would-be reformers, who believe the answer to everything lies in good management, should ponder this phrase". - Jean-Patrick Connerade.

** Former World Bank officials Warren C. Baum and Stokes M. Tolbert in a recent book cite World Bank experience to maintain that developing countries should use the technology most germane to their circumstances. "Yet in countless instances ... developing countries have adopted or retained technologies clearly unsuitable to their circumstances. Why does this happen? Foreign consultants or advisers may advocate the technology with which they are most familiar. Local engineers, if educated abroad or the heirs of a colonial legacy, may have acquired a similar bias in favour of advanced technology ...".

A case in point is Togo's, for Classical Technologies. Under the Caption *How to Ruin a Country*, Richard Gersler, the coordinator of development policy of four major Swiss non-governmental organisations, has given the details.

"In the mid-70's, the phosphate boom made Togo feel and appear somewhat 'rich'. This attracted foreign investors and developed corruption. As a result, Togo's debt today reaches US$ one billion. ... Togo was the victim of unscrupulous investors - overoptimistic market 'studies', no competitive bidding ... " .

"Case 1: Plastic products made in Togo

"A Swiss flag flutters, alongside those of Denmark and Togo, over the grounds of the firm named *Industrie Togolaise des Plastiques* (ITP). The date is 18 April 1986. The Board of Directors is meeting to discuss the company's financial rehabilitation. But ... there are no Swiss in the meeting.

"A few years earlier, it was different. When, on 19 March 1980, ITP was founded, the capital stock (US $ 3.1 million) was held jointly. ...

"From the beginning ITP operated in the red. By 1984, a loss of roughly US$ 5.1 million had accumulated. The reasons: the bureaucratic management style: (of the 130 current employees, 35 to 40 at best will be able to 'survive' the reorganisation); the productive capacity of PVC tubes for water pipes, of plastic buckets, plastic chairs, etc. was from the start several times too large. ... The export to neighbouring countries was severely hampered because plastic products are often manufactured locally and, as in Togo, protected from foreign competition. ...

"Case 2: A corrugated-iron roof over one's head

"In 1977, Rolf .... owner of the Berg AG of Cologne and Basel, suggested to the government of Togo the construction of a corrugated iron factory. He documented the profitability of a corrugated iron factory in Togo with an annual output of 12,000 tons, based on a 24-hour, three-shift operation with exports to Niger, Burkina Faso and Benin. Cost: Swiss francs 12,058,900 for the turnkey plant.

"Togo's government let itself be persuaded. As various experts of Togolese nationality as well as foreigners unanimously confirm, such deals invariably presuppose corresponding 'gifts'. 10 to 15 percent of the total cost were the norm. ...

"In March of 1985, an external commission submitted an extensive report on behalf of the Togolese ministry for state enterprises. The team of three came to the conclusion that the actual value of the completed plant was as of 1980, only Swiss francs 5,351,000. ... Thus, because it did not invite international bids, Togo ended up overpaying" by a hundred per cent.

"Case 3: The technologically outstanding steel mill

"The steel mill, inaugurated in 1979 ... has never managed to operate out of the red. BBC, leader of a consortium, delivered the turnkey plant valued at Swiss francs 85 million. ... The complete plant has now been leased by the government of Togo to the American entrepreneur John Moore for 10 years. He is paying for this a total of US$ 7 million. ... Comparing this with the investment value of 85 million Swiss francs, Togo has to shoulder a huge loss. ...

"From debt rescheduling to debt rescheduling"

In 1980, Togo's foreign indebtedness "reached one billion dollars. This equalled 100 percent of the country's national income". This led to debt regulating and Togo's reputation within the international donor community, as a model pupil.

"In 1987, however, the good relationship between the IMF and the government of Togo was interrupted". The President of the country "did not let the opportunity slip to buy a presidentital jet ... and to increase military expenditures. ..."

(IFDA Dossier of May/June 1989).

This is also the classical area of "negotiated Technology Transfer"* and the area on which centrally-planned economies of the second world as well as some of the developing countries (like India in the beginning) placed their strongest emphasis. Any country which wishes to industrialise will have to develop one or more of the technologies listed above (as, for example, USSR, Japan and South Korea initially had to).**

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* So beloved of our diplomats.

** In this paper, we have used the generic word Technology, whenever we wish to refer to the whole area of Technology - whether "Low" or "High". ("Low" Technology is not used in any pejorative sense. Perhaps "Classical" Technology would give a better flavour of what is meant). Like "Basic" versus "Applied " Sciences, the distinction between the two areas of Technology , "Low" versus "High", is often blurred, particularly when methods and tools of "High" Technology - like micropocessors - are used in industrial products of "Low" Technology. (By "High" Technology, we mean specifically the "Science-based Technology" of today). One should say it clearly and emphatically that "Low" Technology is like "Basic Sciences" - it must be developed by any nation wishing to industrialise - particularly the "design" and fabrication part of it.

A nation may develop engineering expertise and a skilled and disciplined work-force alone in the first instance - i.e. only Development and no Research. Such an attitude towards Research will, of course, eventually prove short-sighted - particularly in the areas of Sciences in Application , or for modern "High" Technology, which the developed countries will not lightly part with.

D) Finally, there are five areas of **Science-based "High" Technology** which, in the conditions of today, may comprise:

(1) New Materials (including composite materials and High Temperature Superconductors); (2) Communication and other Sciences which consist of two types of sub-disciplines:

(2a) Microelectronics (including Development of Software; Microprocessors, Computer-aided Design; Fabrication of Microchips and their applications to other industries, for example, the automotive); and

(2b) Photonics (including Lasers and Fibre Optics);

(3) Space Sciences; (4) Pharmaceuticals and Fine Chemicals (5) and finally, for the 21st century, Biotechnology,* and gene-splicing, so full of promise of a true revolution in the methods of Agriculture, Energy and Medicine.**

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* "Biotechnology thrives on new knowledge generated by molecular biology, genetics and microbiology, but these disciplines are weak, often nonexistent, in the underdeveloped world. Biotechnology springs from universities and other research institutions - centres that generate the basic knowledge needed to solve practical problems posed by society. But the universities of the underdeveloped world are not research centres. ... And the few creative research groups operate in a social vacuum; their results might be useful abroad, but are not locally. ... Biotechnology needs dynamic interactions among the relevant industries. These interactions, however, are weak in countries in which science is perceived as an ornament, not as a necessity. ... Biotechnology requires many highly skilled professionals, but ... underdeveloped nations lack sufficient people well-trained in the pertinent disciplines. ... Economic scarcity and political discrimination induce professionals and graduate students to emigrate or abandon science altogether". (Guest editorial from the journal "Biotechnology", September 1986).

** "During the past year or so the bio-revolution has begun to spin off significant new developments in areas of agriculture that are far apart. These include the following: 1) A gene-splicing breakthrough that could shortly revolutionise the economics of dairy farming with the first bovine somatotropin (BST), a genetic growth hormone that offers increases in milk yields of 15 to 20 per cent without raising feed costs; 2) Calves can now be 'harvested' from cows at a greatly increased rhythm thanks to embryo duplication techniques that enable a single cow to produce twin calves five times a year; 3) Industrial tissue-culture techniques may soon eliminate the need to grow whole plants ... Biotechnology specialists, notably the UK company Plant Science, are already producing digitalis, opium, ginseng and pyrethrum by culturing root cells in a fermentation vessel.

"Big chemical companies like Monsanto and Sandoz have bet ... on strategies of switching emphasis away from industrial chemicals into biotechnology. Their sights are firmly set on an industry that is forecast to grow from its present turnover of around $25 billion a year to an annual $100 billion by the year 2000." - Giles Merritt (November 1987).

"High" Technology differs from Classical "Low" Technologies in that high expertise in the relevant Basic Sciences (like Physics or Chemistry, or Biology, or Mathematics) is crucial. The materials used are minimal in their bulk and size.

Very few of the developing countries, with the exception of the "Confucian belt" countries - like China or Singapore - or Brazil are conscious of the need for or have made progress in "High" Technology, the general feeling being that this whole area is beyond them.* It is this feeling of lack of interest and faith in their own scientists and technologists that one must

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* "Business leaders attending the recent International Telecommunications and Informatics Trade Show (TECNOTRON 89) were invited to try out a computerised system that nine developing countries are using to exchange technological information and investment and trade opportunities.

"The unique system was on display at the pavilion set up by the Technological Information Pilot System (TIPS), a project supported by the U.N. Development Programme (UNDP) and the U.N. Centre for Science and Technology for Development (UNCSTD).

"Nine developing countries - Brazil, China, Egypt, India, Mexico, Pakistan, Peru, the Philippines and Zimbabwe - are currently involved in the project.

"Visitors to the TIPS pavilion had access to such information as a Chinese machine tool factory's search for equipment to manufacture plastic injection moulds and a Peruvian manufacturer's offer of turbines, generators and speed regulators for small hydroelectric plants.

" 'Traditionally, Western industrialised countries have been the source of most technical information for developing countries. This has allowed those countries to dominate the international market, based on their technological leadership and control of communication systems', said Gustavo Flores, Director of TIPS in Peru". (Abraham Lama, Special United Nations Service Bulletin (SUNS), No. 2159, 20 May 1989).

fight against since the future undoubtedly lies here. This is on account of the enormous value-added potential of the industries based on "High" Technology** and the possibilities of exporting its products. There can be little "High Technology Transfer" from the North (unless this is of yesteryear's Technology) because no one will now want to sell*** - one has

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** The present value-added contribution of High Technology to the US and Japanese economy is estimated to be 29% while for Europe the contribution is of the order of 22%.

*** "Most entrepreneurs would sooner sell their mothers than their technology. Not so Sun Mircrosystems. Through much cash, sweat and tears, California's Sun has struggled to create desktop computers embodying some of the fastest microprocessors, flashiest graphics and most-convenient communications software now on the market. But instead of guarding its innovations, Sun will license vital computer technologies to anybody who wants them - friend or foe. Instead of the doom which Sun's critics have long predicted, Sun's open-door policy has made it one of America's fastest-growing computer companies, expanding to annual sales of $2 billion in seven years.

"On May 30th Sun licensed its secrets to Japan's Toshiba, a big Japanese electronics group and one of the bogeymen of America's industry. Doomsayers, and some of Sun's rivals, began to speculate that Sun might be a charity instead of a business - or part of a Japanese conspiracy to crush American industry. Toshiba, they say, will use the technology first to wipe out Sun, then its rivals in the market for powerful, $10,000-40,000 desktop computers called engineering workstations, and finally the rest of the American small-computer industry. Remarkably, the licensing deal does not prohibit Toshiba from competing directly with Sun in any market.

"Not content to aim at the engineering-workstation market, where worldwide sales total only 300,000 units a year, Toshiba is planning to use Sun's technology to make a splash in the much larger personal-computer market, where worldwide sales total over 18m units a year.

"Sun may indeed be among those who will feel the heat from this deal. Recently, it has tried to move down-market into personal computers. Armed with Sun's technology, Toshiba could enjoy a hefty advantage in this market because it already has an established network of retailstores selling its popular laptop computers, while Sun has so far sold its engineering workstations direct to the customer.

"Yet Sun reckons that the benefits of sharing its technology far outweigh the problems of extra competition". (*The Economist*, 3 June 1989, p. 94).

to learn to reinvent from published literature.*

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* This is what the Japanese claimed to have done in many instances. " ... we at Sony took the basic transistor and redesigned and rebuilt it for a purpose of our own that the originators hadn't envisioned. We made a completely new kind of transistor, and in our development work, our researcher, Leo Esaki, demonstrated the electron tunneling effect, which led to the development of the tunnel diode for which he was awarded a Nobel Prize seventeen years later, after he had joined IBM. ... The highly educated work force of Japan continues to prove its value in the field of creative endeavor. In the recovery from the war, the low cost of this educated labor was an advantage for Japan's growing low-technology industry. Now that the industrial demand is for high technology, Japan is fortunate to have a highly educated work force suited to the new challenge". - Akio Morita , "Made in Japan". (I would like to recommend this book by the man who founded "Sony" of Japan, to anyone interested in Science and High Technology).

If one still persists in thinking of Japan as a country which has lived off borrowed technology, creating little basic knowledge, it is worth pointing out that the situation is fast changing. Thus, the finest Encyclopaedic Dictionary of Mathematics today is the Japanese, translated into English by the Massachusetts Institute of Technology Press (1977).
(See , in particular, Appendix XIV).

Of the four aspects of Sciences and Technology which have been mentioned above, the first to be developed so far as our countries are concerned, is Classical "Low" Technology. The next may be Science in Application. (This is assuming that expertise in Basic Sciences is already available). The last to develop, as a general rule, is Science-based* "High" Technology.**

To conclude this section, for a moderate sized developing country, there is no option to developing all the four areas of Science and Technology enumerated above.

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* The socialist regimes by and large have taken to Science and the "Low" Technology - particularly "heavy" Technology - as a religion, and with the same fervour. (They are now waking up to the possibilities in civilian "High" Technology).

** There are, of course, entrepreneurial considerations for the development and export of products of one technology versus another, important areas for the economist's judgement: (for example, the crucial choice before a country between import substitution versus emphasis on exports, discussed by Dr. Hyung Sup Choi, former Minister of Science and Technology of South Korea). These will not be elaborated here. (His paper - reproduced in Appendix XVI - was specially written for the South Commission).

In this context, the following recipe for accelerated development (which employs the modern ideas of Technology Blending) may be relevant: "Korea's industrial structure is mainly based on four groups of industries called Hyundai, Samsung, Daewoo and Goldstar. The Hyundai group started as a construction company, then expanded into manufacturing ships, petrochemicals, autos, machinery and electrical and electronic goods. In 1986, the total of its overseas exports was $15 billion. The Samsung group started with sugar refining, then textiles, petrochemicals, paper, jet engines, semiconductors, optical fibers, computers, electronics, T.V. sets and microwave ovens, with a net sales of $14 billion and export earnings of $6 billion, with 120,000 employees in 1986. Goldstar started from tooth paste containers, then soap, radio tubes, telephones, colour T.V. and microwave ovens, reaching a total sales of $4 billion with 51% exports in 1986.

" ... In this expansion process, as the excess capacity developed, exploration (i.e. Research and Development) into manufacturing other products was started - such as the radio vacuum tube, telephone sets, telephone switching equipment, electric fans, radios, transistor radios, T.V. sets, colour T.V. and VCRs". - Dr. Abdul Ghani.

4. WHY HAS SCIENCE AND TECHNOLOGY LAGGED BEHIND IN THE SOUTH?

There are three reasons why Science and Technology in the Third World countries in general have suffered.

A) i) Lack of Meaningful Commitment towards Science, either Basic or Applied. By and large, there has been scant realisation that Science can be applied to development as, for example, there was in Japan at the time of the Meiji Restoration around 1870 when the Emperor took five oaths. One of the oaths set out a national policy towards science - "Knowledge will be sought and acquired from any source with all means at our disposal, for the greatness* and security of Japan". The consequences of this lack of commitment have been weak universities, few research centres for Applied Sciences, sub-critical and isolated communities of scientists (with scant provision for infrastructure, for scientific literature and international contacts), weakness in scientific (and technological) education (discussed further in Section 7) and little expenditures on Science, whether Basic or Applied (discussed in Section 5).

ii) No Commitment to Self-Reliance in Technology. In technology, by and large, few of our Governments have made it a national goal to strive for self-reliance. The situation may be somewhat better for "Low" Technologies but is dismal where High Technology is concerned. We have paid little heed to the scientific base of high technology, i.e. to the truism that science transfer must always accompany high technology transfer, if such transfer is to take.

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* Japan's "election" into the rich man's club - the OECD - did indeed follow upon mastery and utilisation of modern Science and Technology.

B) Inadequate Institutional and Legal Framework. In respect of political actions needed, there is the necessity to have institutional and legal enactments. For example, Dr. Hyung Sup Choi spearheaded, on the institutional side, the creation of the Korea Institute of Science and Technology (KIST), the Korea Advanced Institute of Science (KAIST), the Korea Technology Finance Corporation (KTFC) and others, while, on the legal side, there was the enactment of several important laws for the development of science and technology. These included: the Law for the Promotion of Technology Development of 1972,* which provided fiscal and financial incentives to private industries for technology development; and the Engineering Services Promotion Law of 1973 to promote local engineering firms by assuring markets on one hand and performance standards on the other.

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* Apparently, among these, the most important was the Law for the Promotion of Technology Development of 1972. This Law was passed to encourage the private sector to adapt and improve imported science and technology, and to develop domestic science and technology through the R&D activities of government subsidized laboratories. The government took a follow-up step in 1977 by extending this law, encouraging tax and financial incentives to a wider range of industries, while making Research and Development (R&D) activities mandatory for strategic industries. Presumably all these laws were enforced. It is this type of care and concern for the utilisation of Applied Sciences and Technology which is important and without which no amount of expenditure on Science and Technology is likely to be meaningful.

C) <u>The Manner in which the Enterprise of Science Has Been Run</u>. Science depends for its advances on towering individuals. An active enterprise of Science must be run by scientists themselves (and not by bureaucrats)* or by those scientists who may have been active once, but have since ossified. Science flourishes on criticism and toleration of opposing views. This has to be jealously safeguarded within our societies.

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* Some bureaucrats (who do not even know what High Technology is) have, for example, taken upon themselves the task of setting up of High Technology Parks in some countries of the South. In a well-ordered society, this would be unacceptable.

5. THE SUB-CRITICAL SIZE OF SCIENCE AND TECHNOLOGY IN THE SOUTH *

A) An index of the sub-critical size of Science and Technology is the numbers of those engaged actively in this activity in the Third World. The UNESCO figures paint a different picture for the South and the North. In the North, an order of several thousand inhabitants per million** are - engaged in Research and Development (and the numbers keep rising year after year) - while those similarly engaged in the South seldom exceed more than a few hundred.

The Chinese figures in this context are revealing. According to Professor Lu Jiaxi, former President of the Chinese Academy of Sciences - speaking on Chinese Science at the Second General Conference of the Third World Academy of Sciences in Beijing in September 1987 - the Chinese had fewer than 500 researchers in 1949 altogether - less than one per million of population. The situation in most developing countries today is similar to that in China in 1949. (There are now 300,000 researchers in China and the country is approaching international norms, with a factor of 600 increase in

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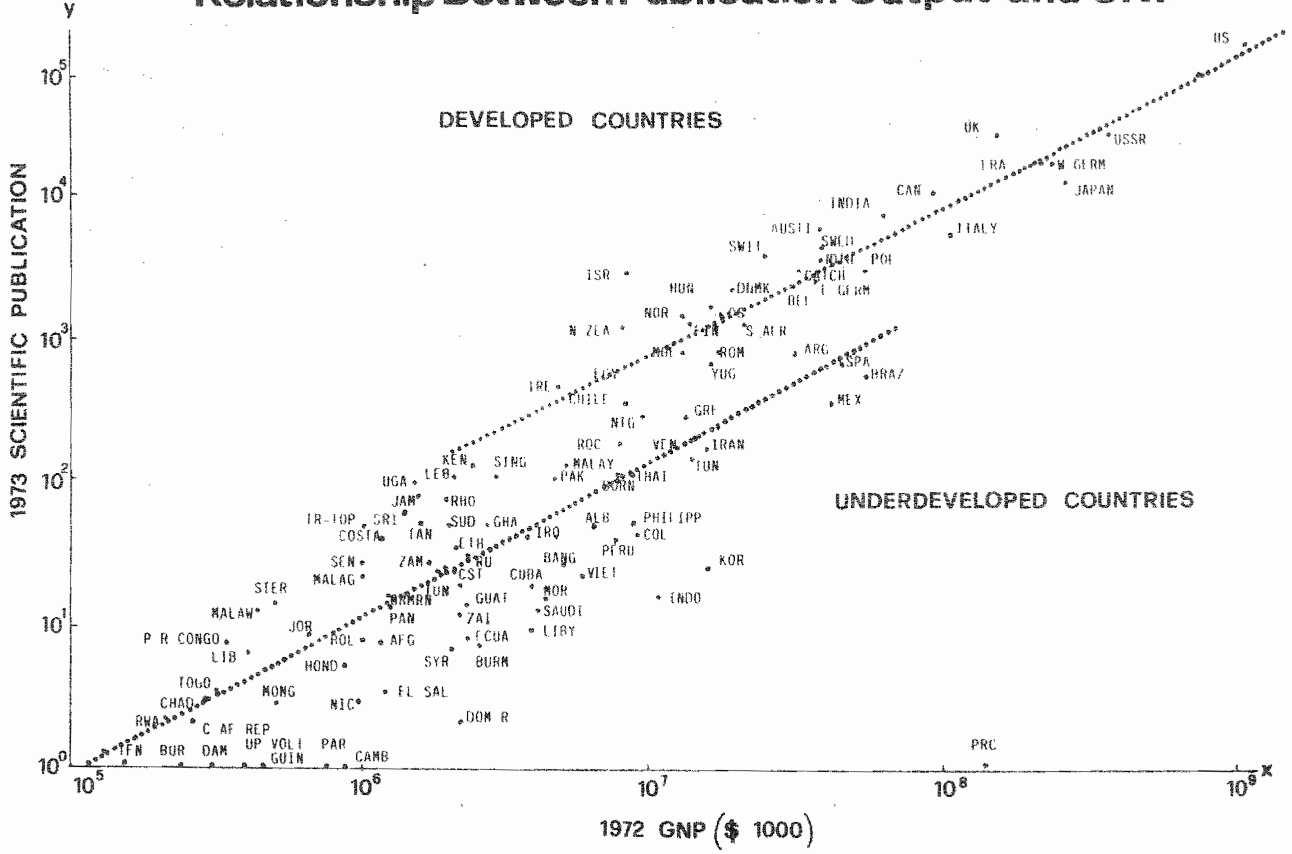
* According to an empirical law discovered by the late Professor Jolla Price of Yale University, with few exceptions, a country's output of scientific research is directly proportional to its spending on Science and is correlated with its GNP. (See Figure on next page).

** It has been estimated that the UK would need 800 doctoral-standard physicists every year for the next five years. (Compare these numbers with those of Pakistan's present total of 49 Ph.D's in Physics in all of its 19 universities (with nearly twice the population of the UK). Pakistan has now sent some 700 students for Ph.D. training in all fields abroad.

J. Davidson Frame

Social Studies of Science (SAGE, London and Beverly Hills), Vol. 9(1979), 233-46

Relationship Between Publication Output and GNP



40 years).*

Regarding the numbers engaged in Science and Technology promotion, developmental adaptation and modification, plus extension and utilisation, the situation is the same.

B) One of the revealing indices of the size of Third World Science and Technology is the funding which the South provides for Research, Development and Utilisation of Science and Technology. (This is correlated with the smaller numbers engaged on Science and Technology). To appreciate this, one has only to look at Tables I, II and III which give the Defence, Education, Health and Science Expenditures as percentages of GNP, both in the South and the North.

The point about the Tables is the following: Both the industrialised and the developing countries spend 5.6% of their respective GNP's on defence. The educational expenditures are also similar - 5.1% for the industrialised versus 3.7% for the developing countries. For health it is 4.8% for the industrialised versus 1.4% for the developing countries - admittedly, a difference, but not as striking as that for Science and Technology. The ratio of expenditures on Science and Technology (between the North and the South) is one full order of magnitude (a factor of 10 or so).

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* According to Professor T.R. Odhiambo, "Africa has, by far the fewest R&D scientists and engineers compared to other regions of the world. While, in 1978, Africa (excluding Arab States) had 53 scientists and engineers for every one million inhabitants, Asia (excluding Japan) had 99, Arab States had 202, Latin America (excluding the Caribbean) had 209, and Europe had 1,632. The comparable figures for the USA, Japan, and the Soviet Union were 2,685; 3,548; and 5,024 respectively.

"Because of the minuscule size of the African scientific community in relation to the enormous agenda for science-driven development in their continent, the African people and their leaders need to create a special enabling environment for the embryonic scientific community to develop and grow; to challenge them with worthwhile tasks; to establish and nurture an intellectual environment that encourages creativity; to provide incentives that they cannot refuse; and to honour them. This must be a conscious, definitive action arising from a committed political decision".

Table I

Defence, Education and Health Expenditures in US dollars (1984) (as % of GNP)

	Population (x 1,000)	GNP (million US$)	GNP Capita(US$)	Defence (%)	Education (%)	Health (%)
Industrialised countries	1,125,033	11,019,363	9,795	5.6	5.1	4.8
Developing countries	3,651,353	2,697,982	739	5.6	3.7	1.4
Africa *	469,823	302,494	644	3.9	3.8	1.1
Middle East**	148,666	351,798	2,366	17.3	6	2.5
South Asia	992,628	266,330	268	3.5	2.8	0.8
Far East ***	1,513,771	726,496	480	5.9	3.2	1.2
Latin America and Caribbean	394,718	752,688	1,907	1.6	3.7	1.3

Based on *World Military and Social Expenditures*, by Ruth Leger Sivard, World Priorities, Inc., Washington D.C., 1987.

* Less South Africa

** Less Israel

*** Less Japan

Table II

Industrialised Countries' Expenditure on Science and Technology

Country	Population Millions	GNP per capita (US$) 1985	Public Expenditures in Education (% of GNP)	Scientists/ Engineers in R&D (per million inhabitants)	Expenditure on R&D * (% of GNP)
France	55.17 (1985)	9,540	5.8 (1983)	4,500 (1988)	1.8 (1980)
Federal Republic of Germany	61.0 (1985)	10,985	4.6 (1984)	3,000 (1988)	2.5 (1985)
Japan	120.75 (1985)	11,300	5.6 (1984)	6,500 (1988)	2.6 (1984)
Netherlands	14.48 (1985)	9,290	6.9 (1984)	4,500 (1988)	2 (1984)
U.K.	56.6 (1985)	8,460	5.2 (1984)	3,200 (1988)	2.3 (1980)
U.S.A.	239.3 (1985)	16,690	6.8 (1984)	6,500 (1988)	2.6 (1984)

* Based on UNESCO statistics (1987). (These figures may include: application, diffusion and commercialisation and venture capital for technology provided by governments as well as by private industry, plus defence R&D).

Table III

Estimated Expenditure for Research and Development as Percentage of G.N.P.

(Selected Countries)

ASIA		LATIN AMERICA AND CARIBBEAN			AFRICA	
Bangladesh (1975)	0.2	Argentina	(1980)	0.5	Algeria (1975)	0.3
India (1984)	0.9	Brazil	(1984)	0.6	Egypt (1984)	0.2
Indonesia (1984)	0.3	Chile	(1980)	0.4	Nigeria (1980)	0.3
Iran (1975)	0.5	Cuba	(1985)	0.7		
Iraq (1975)	0.1	Mexico	(1984)	0.6		
Pakistan (1980)	0.2	Peru	(1984)	0.2		
Philippines (1984)	0.2	Venezuela	(1984)	0.4		
Singapore (1984)	0.5					
Sri Lanka (1984)	0.2					

(From UNESCO Statistical Yearbook 1987)

The industrialised countries spend 2-2.5% of their GNP's (on Research, Development and Modification, Adaptation plus the Utilisation of Science and Technology) versus less than 0.3% (on UNESCO's estimates, Table III) spent in most developing countries. (There are some few exceptions - the most notable ones which have reported to UNESCO being Argentina, Brazil, Cuba, India, Mexico and South Korea, which spend more than 0.5% of GNP on Science and Technology).* Even though one may argue that spending on Science and Technology is only a necessary condition for the developmental aspects of Science and Technology and not a sufficient one (on account of other motivational factors which may be just as important), it remains a fact that the industrialised countries are expending (in GNP terms) on the average some nine times more every year on Science and Technology than the Third World. We in the Third World are just not serious about Science and Technology. The profession of Science and Science-based Technology is hardly a respectable - hardly a valid profession in the South.**

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* We were heartened to hear from our colleagues on the South Commission that from 1989, during the next five years, Venezuela's expenditures on Science and Technology may go up to 2% of GNP from its present 0.4%, with state action for the utilisation of scientific and technological research. At his inauguration ceremony on 2 February 1989, President Carlos Andres Perez promised that "after reorganising the Federal Government, he would make Science and Technology a top state priority" (Special United Nations Service Bulletin, No. 2094 of 6 February 1989). We were told that the Philippines' expenditures may likewise go up from 0.2% to 1.5% and Brazil's, from its present 0.6% to 2% of GNP by 1990. Cuba, we were told, is already spending 0.9% of its GNP on Science and Technology. Iran is expected to raise its spending on Science and Technology from its present 0.5% to 1% of GNP with immediate effect and to 2% later. South Korea is already spending on Science and Technology 2% of GNP. This will rise to 3% by 1992! Bangladesh has promised to increase its GNP spending from the present 0.2% to 1.1% by the end of five years, while Pakistan is considering increasing its spending from the present 0.17% to 1% of GNP.

** In the British Colonial Empire, Britain did not leave behind the concept of a Scientific Civil Service (which, incidentally, has been part of the United Kingdom's own administrative and professional structure for a long time).

6. STEPS NEEDED TO MAKE SCIENCE AND TECHNOLOGY STRONG IN DEVELOPING COUNTRIES *

A) The Five Classes of Communities in a Developing Society which must Cooperate. There are five classes of communities in a developing society which could be involved in the building up and utilisation of the enterprise of Science and Technology in our countries. First, there are our rulers who determine the priorities. Second, there are the planners, the economists and the international bankers who advise them. Third, there may be the entrepreneurs with their management skills and risk capital. Fourth are the educators and media-men** - plus the religious leaders*** in some of the

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* "Although many governments (in the West) had, from the beginning of this century, supported laboratories for particular sectors, it was only in the early 1960s that science and technology began to be considered in strategic and policy terms. The concept of science policy, to a large extent derived from our work in OECD, was initially greeted with some suspicion. I remember that when we announced our intention of convening the first meeting of ministers responsible for science, the Minister of Education of the Netherlands visited Paris in an attempt to persuade the Secretary General of OECD to cancel the meeting. It was argued that science, if it had any policy implications at all, was an element of cultural policy and that to discuss it in an economic context was a sort of prostitution. These attitudes soon changed, and both science and technology began to be discussed in investment terms". - Alexander King, President, Club of Rome.

** "Science and Technology development gains momentum when a suitable environment for its popularization is created. The creation and promotion of such an environment is a prerequisite for science and technology development, particularly in a country where social and economic patterns and customs are bound by tradition. ... Korea has launched a movement for the popularization of science and technology as an integral part of its long-range science and technology development plan. The movement aims to motivate a universal desire for scientific innovation in every one in all aspects of their lives. It has been led by the Ministry of Science and Technology, the Korea Science Promotion Foundation, and the Saemaul Technical Service Corps in cooperation with concerned government agencies, industry, academic circles, and the mass-communication media. ... This movement is in no way conceived as the special province of scientists and engineers, although this group can provide key support and resources in view of its pertinent talent and knowledge" - Hyung Sup Choi.

*** The religious leaders in some of our countries can play a leading role in popularising Science and Technology for the masses. Our Scriptures uniformly emphasise the value of science in recognising Allah's design and of technology in mastery of nature. If only the divines could be persuaded to introduce modern Sciences and Technology into the curricula of their own seminaries!

developing countries who interact directly with the public. Fifth and last, come the scientists and the technologists.*

Different societies have differing experiences in regard to the primacy of one or more of these classes. For example, the Brazilian experience has been one of closest collaboration between the rulers - the military men in the past - and the economists and the scientists and the technologists.** For India, Nehru's influence - no doubt conditioned by his background as a Science student at Cambridge*** - was paramount in laying down the traditions for scientific and technological research. The Chinese experience has been similar, where statesmen like Chou-en-lai and the scientist have collaborated actively. The same happened in the USSR (where, starting with

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* The discerning reader may have noticed that I have not emphasised the general public itself among the five categories which I have enumerated. This is due to the circumstance that in most of our (dictatorially-run) southern countries, there is no credible public opinion. (The first essential for such an opinion to be created is the existence of a pressure group of scientists and technologists. On account of the small numbers involved, this is hardly, if ever, achievable).

** Apparently the educational system in Latin America places a high emphasis on an engineering degree followed by a doctorate in economics.

*** "Modern technique is not a matter of just getting a tool and using it. Modern technique follows modern thinking. You can't get hold of a modern tool and have an ancient mind. It won't work".

"I realised that science was not only a pleasant diversion and abstraction, but was of the very texture of life, without which our modern world would vanish away ... It was science alone that could solve these problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people". - Jawaharlal Nehru.

Peter the Great) Lenin and others were responsible for the building up and for the utilisation of Science and Technology.*

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* Seventy years ago, the Soviet Academy of Sciences was asked to expand its numbers and was set the ambitious task of excelling in all sciences. Today it numbers a self-governing community of quarter of a million scientists and technologists working in its own institutes, with priorities and privileges accorded to them in the Soviet system that others envy. According to Academician Malcev, this principally came about in 1945, at a time when the Soviet economy lay shattered by the war. Stalin decided at that time to increase emphasis on sciences. Without consulting anyone else, he apparently decided to increase the emoluments of all scientists and technicians connected with the Soviet Academy, by a factor of three hundred per cent. He wanted bright young men and bright young women to enter massively the profession of scientific research and he succeeded.

Then there is the case of Japan where the ambitions of the Meiji statesmen (and now MITI) coincided with the patriotic feelings of the scientists and technologists themselves.* In all these examples, the fortunate scientist and technologist worked closely, in execution and advice, with rulers,** who set the priorities for the country's development. <u>This is the type of political action needed for the entire South, without which nothing much will happen</u>.

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* This paper is about civilian Science and Technology but there is a strong correlation between strong local Science and Technology and Defence. We were told that one of the drives behind the Japanese acquiring Science and Technology in the Meiji era was to make their country strong for defence. They had before them the sad examples of India and China succumbing to the foreigner because of the inferior scientific and technological base from which they operated.

A similar sentiment has been expressed in a recent (August 1988) issue of The Herald of Pakistan: "The Gulf war has demonstrated one important fact: that religious fervour alone is no match for hi-tech weaponry. All religious 'fundamentalism' is today powerless if it is unable to arm itself with the instruments and weapons that only modern science and technology can provide". As if this had not already been shown by the experience of the Sudanese at the battle of Omdurman in the year 1898!

In this same context, the role of "research" versus "development" must not be forgotten. As early as 1799 - against the opposition of the Ulema and surprisingly, even of a section of the military establishment - Sultan Selim III did introduce the subjects of algebra, trigonometry, mechanics, ballistics and metallurgy into Turkey. He imported French and Swedish teachers for teaching these disciplines. His purpose was to rival European advances in gun-founding. Since there was no corresponding emphasis on research in these subjects, and particularly, in materials research, Turkey could not keep up with the newer advances being made elsewhere. The result was predictable: Turkey did not succeed.in keeping up with its European rivals Then, as now, technology, unsupported by science, would not flourish.

** Defence Expenditure (on costly development of missiles and the like), can be a debilitating drain on a nation's material as well as on its scientific and technological resources (as Gorbachev's USSR and Reagan's US, as well as (on a humbler scale) China, India, Brazil (and Pakistan) are discovering to their cost).

B) Generous Patronage and Minimal Expenditures on Science and Technology. No Science and Technology - Research, Development and their meaningful Extension and Utilisation - is possible without a nation spending an inescapable minimum of funds on it. In the industrialised countries, as a general rule, some 2-2.5% of GNP is made available - by the State as well as by private industry - for the four broad areas mentioned earlier. So far as expenditures are concerned, the funds spent on Basic Sciences Research in the North amount to some 4-10% of a nation's educational budget - taken as a unit* - while roughly the same amount (4-10%) is spent on Applied Science

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* We could have taken any other indicator to estimate the desirable expenditures on Science and Technology. We have chosen the educational expenditures (rather than defence, for example) as a suitable unit.

Research*, and twice as much (8-20%) on Research and Development**

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* These modest expenditures are necessary to secure critical sizes of Science and High Technology communities, and for providing them with tools to do their work. It came as a surprise - certainly to the author - that such outlays are frowned upon, particularly by the economists, as wasteful luxury, even after it is demonstrated that these would increase the GNP manifold - if only by bringing about agricultural plenty - another Green Revolution and better health. (Most economists seem unaware of the work of Professor T.W. Schultz and Sir Arthur Lewis, Nobel Laureates in Economics for 1979, who have argued strongly for educational expenditures as a productive activity, and of Professor R. Solow, Nobel Laureate in Economics for 1987, who has similarly argued for Applied Sciences).

** Professor Simon Kuznets, Nobel Laureate in Economics in 1971 has particularly suggested that "mass application of technological innovations" is the secret of rapid growth.

Quoting him, the distinguished economist, Professor Michael Todaro, in his book *Economics for a Developing World* has remarked: "Six characteristics of modern growth are highly interrelated and mutually reinforcing. High Rates of per capita ouput result from rapidly rising levels of labour productivity. High per capita incomes in turn generate high levels of per capita consumption, thus providing the incentive for changes in the structure of production, since as incomes rise the demand for manufactured goods and services rises at a much faster rate than the demand for agricultural products. Advanced technology required to achieve these output and structural changes causes the scale of production plants and the characteristics of economic enterprise units to change in both organisation and location. This in turn necessitates rapid changes in the location and structure of the labour force and in status relations among occupational groups (for example, the income shares of landlords and farmers decline while those of manufacturers and industrialists tend to rise). It also means changes in other aspects of society, including family size, urbanisation and the material determinants of self-esteem and dignity. Finally, the inherent dynamism of modern economic growth, coupled with the revolution in the technology of transportation and communication, necessitates an international outreach on the part of those countries which developed first".

related to "High" Technology (a total of 16% to 40%).* Thus, even if the developing countries adopt, as a desirable minimum, the lower figure of 16% (around 1/6) of their own educational budgets on Science and Science-Based High Technology, this should provide the "colossal" figure of 14.5 billion dollars from the South's own domestic resources, according to the estimates made by the Third World Academy of Sciences (TWAS). No Science-based development will accrue (and no enhancement of GNP) unless we make these basic outlays.** Once again it is to be emphasised that this is NOT a recommendation to diminish the education budget (spending on this account is low as it is) but to find the additional spending on Science and High Technology through general belt-tightening*** and by diminishing, for example, from Defence expenditures.****

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* I am told that in Egypt, three million dollars was spent in setting up a factory for the manufacture of thermionic tubes. The factory was built in the same year that transistors were perfected and began to invade the world markets. The recommendation to set up the thermionic tubes factory was doubtless made by foreign consultants. It was, however, accepted by Egyptian officials who were not particularly perceptive of the way science was advancing, and who presumably did not consult the competent physicists in their own country.

** The scientists must try their best to assure that adequate returns on the funds spent on Science and Technology are paid back to the nation. This is because one looks upon such spending as a sacred trust, - in particular for the 35 countries of the "Real South" (in Gerald Segal's definition), each with a population of one million or over and a GNP less than $400 per capita and which together account for nearly half of the world's population. The twelve in Asia include China, India, Laos, Vietnam, Kampuchea, Burma, Bangladesh, Bhutan, Nepal, Pakistan, Sri Lanka and Afghanistan. The twenty-three in Africa include Madagascar, Mozambique, Malawi, Burundi, Tanzania, Rwanda, Zaire, Uganda, Kenya, Somalia, Ethiopia, Burkina Faso, Sudan, Chad, Niger, Mali, Central African Republic, Ghana, Guinea, Sierra Leone, Senegal, Togo and Benin.

*** "The taxation potential in underdeveloped countries is rarely fully exploited ... no more than one-fifth or possibly one-tenth of what is due (is collected).

"In many underdevieoped countries the low revenue yield of taxation can only be attributed to the fact that the tax provisions are not properly enforced, either on account of the inability of the administration to cope with them, or on account of straightforward corruption."- N. Kaldor, Cambridge University.

**** One hopes that the reduction of "debt burdens" and the consequent relief may provide yet another source for enhancing expenditures on Science and Technology. (According to estimates made by Dr. D.R. Bes, debt servicing alone costs the debtor countries some 7% of their GNP, half of which is actually paid). I do, however, hope we do not wait upon this saving before the recommendations of this note are adopted.

C) Utilisation of and Reciprocal Commitment and Responsibility of Scientists.

i) Feeling of Inferiority regarding Indigenous Science and Technology.

Technological aand scientific dependence of the Third World is the state of mental subordination that arises from a strong sense of inferiority towards Science and Technology. This feeling, which is particularly serious among decision-makers in general, tends to inhibit scientific and technological initiatives in the South.* This is a barrier to be overcome, so far as autonomous development is concerned.**

I would like to suggest that the time has come when our courts of state should once again be adorned with scientists and technologists. I am reminded of the story of King Arthur of legendary fame; at his Court there was a Court Magician; his name was Merlin. Merlin was responsible for using magic for forging steel for swords and for providing magical medicinal potions. The scientists are the Merlins of today. They can perform feats of magic undreamt of by Merlins of yesteryears. They can, indeed, transform society.

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* The economist and the planner, for example, must learn that they should show respect to and employ the scientist and the technologist within the country before thinking of hiring scientists and technologists from abroad. Wherever this has happened, like in Brazil, where indigenous economists have worked hand in hand with the indigenous scientists and technologists, the country has taken phenomenal steps in growth.

** It is also important that scientists and technologists from the South should band together and exercise pressure on their governments for their due recognition. This is certainly the case for scientific communities in the North.

But in our Third World countries, these Merlins have no place in the affairs of State. Should they not be invited to perform their professional act?*

Some will say - and perhaps rightly - that the Merlins in developing countries are gormless amateurs - they hardly know their applied craft. They choose to live in their own ivory towers, and our Southern societies are thereby forced to import the real Merlins from the North. This may be true, but why is this so? Could this emasculation have come about through the fact that our own Merlins are so few in numbers, and even these few have never been invited to make a contribution to development in their own countries. Not even by their colleagues - the professional economists - who in this metaphor are the High Priests of development. Only experience can teach the Merlin-Scientist the craft of developmental problem-solving, even if he knows his science. This vicious cycle of lack of mutual trust must be broken, hopefully, before the year 2000.

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* The decline of the UK (vs., for example, German) industry has been attributed to a similar neglect. "Many British engineers have pointed out ... the difference between current practice in the UK and in Germany concerning the treatment of engineers in industry. ... In the German firm, specialist engineers with real expertise in the products being manufactured and marketed become full members of the board of directors, but in the British company they would be a small minority at the decision-making level. Many engineers in British industry spend their whole lives cloistered in the R&D department, and have no chance at all to influence the market policies of their companies. This is amazing and delightful to our competitors. I believe it is a cultural problem. ... In case you think this is not a cultural problem, consider the recent press report on the numbers of accountants trained every year in different countries. They read: West Germany - 4000; Japan - 6000; France - 20,000; UK - 120,000! ...

"There has also been a historical bias against recruiting civil servants with expertise in science and technology. Indeed, one often hears that a degree in classics from Oxbridge is a more useful qualification than one in the natural sciences. This is, to say the least, bizarre in the 20th century. I have sometimes had dealings with the secretariat of the Bundesministerium für Forschung und Technologie in West Germany, and was amazed to find it staffed by civil servants with (Science or engineering) doctorates. Needless to say, the level of technical expertise in that ministry is a high one". - Jean-Patrick Connerade.

ii) Reciprocal Responsibility of Scientists and Technologists. A parallel sense of responsibility must also be instilled* by and into the scientists and the technologists in developing countries. Scientists and Technologists are, at present, an insignificant proportion of our populations. They constitute a particular social subculture and as such occupy a particular niche of every society. The relevance of this niche is a function of its explicit articulation and integration with the national development process.

The top-ranking scientist and technologist must, in particular, feel that he is part of a team which is engaged in an exciting venture. Such an articulation depends upon the conscious involvement of the scientific and the technological community in the tasks of socioeconomic development, as well as upon the image of science and technology (and of scientists and technologists) in the minds of the non-scientific population - in particular of decision-makers (politicians, entrepreneurs, managers as well as international bankers).

But after saying this, let this also be said very clearly. This two-way interaction depends as much on the attitude of scientists and technologists

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* One aspect of this sense of responsibility (applicable today much more to developed societies) is the following: "Each new discovery or invention is far more than just a new fact or a new tool; it is a challenge to the assumptions by which people live. If you need convincing of this, spend a few minutes thinking about the effect on society about just three discoveries: radio communications, the internal combustion engine, the contraceptive pill. Each has brought a revolution that is deeper and more final than anything that ever happened in 1789 or 1917!

"When scientists make new discoveries - or engineers come up with new inventions - they experience the satisfaction of answering a question that they have set for themselves. (What is the basic building block of matter? Can a machine be made that can fly?) But for the world at large answering of the question may be only one of many consequences of their discovery. ...

Each new discovery unleashes new possibilities, and new dangers, for society to absorb. ... The work of scientists doesn't serve only to satisfy their curiosity; it affects us all, and though our fears may sometimes seem vague and incoherent, they are not based only on ignorance and superstition.

"In fact, pure unchecked curiosity can be a very evil thing indeed (witness the hideous experiments performed on human subjects by (the German or the) Japanese doctors during the Second World War). ... As we stand on the brink of whole new technologies of genetic manipulation, the possibility of human clones and hybrids and chimeras, Milton's and Marlowe's concept of forbidden knowledge is not something that we'd be wise to dismiss completely". - Chris Beckett. This clearly emphasises the need for a new Hippocratic oath.

themselves towards development. They (and their students) must understand the economic basis of their countries' output and the value of their own work also in this context. They must recognise that as a class, "deserts" come together with "desiring".* One must not hear any more of "Ivory Towers" inhabited by our scientists and technologists.**

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* It may be salutary to remind ourselves that the Council of Scientific and Industrial Research of Australia has never had to look back for its funding, after its remarkable discovery of the value of trace elements in Australian soils for sheep-rearing. Likewise, I understand that there is a Venezuelan discovery of special additives which make heavy grade of Venezuela's crude oil flow faster. This has apparently saved the country hundreds of millions of dollars. It is imperative that such examples (which must have occurred in all developing countries) are made known to other scientists and technologists, to the general public as well as to our rulers.

** In evaluating the economic basis of their work, the scientist and the technologist will legitimately include "the teaching of the young".

D) The Universality of Science and the Brain Drain. One of the troublesome points and one which often arouses unwholesome jealousy for the scientific profession is the international character of Science and Technology and the perceived possibility of migration of scientists.*

i) I believe that one of the best anti-brain drain devices is the one which has been pioneered by the IAEA-UNESCO-run International Centre for Theoretical Physics at Trieste - the Associateship Scheme - whereby distinguished scientists working and living in developing countries have a guarantee of spending from six weeks to three months at the Centre at times of their own choosing, three times during a period of six years. Their fares and living expenses in Trieste are met by the Centre. No salaries are paid. Some 350 physicists working in the Third World are presently Associates of the Centre. After 18,000 visits made during the last 24 years by research physicists from the Third World, there has not been a single case of brain-drain from among the Associates and others who have come to work at this prestigious Centre. There is the need for similar schemes for research workers from other disciplines besides Physics.**

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* It is important to state it clearly and emphatically, that scientists (unlike medical men, for example) do not leave their own countries for trivial monetary reasons. They almost always do so because of a) isolation, b) because of lack of similar individuals to talk to and work with, and c) on account of paucity of scientific literature and similar infrastructure. (This, in turn, of course compounds the problem of ever attaining a critical size of the scientific enterprise).

** Even for Third World economists! For example, the United Nations University Economics Institute (WIDER) in Finland may consider building up a long-term Associateship Scheme of its own to keep the young economists from our countries in constant contact with modern thought.

ii) There are other schemes like TOTKEN, devised by UNDP, which recognise the existence of expatriates and <u>that they have a role to play in the development of their own countries</u>.* This scheme makes it possible for expatriate scientists and technologists to visit their countries on a regular basis.

iii) It is worth pointing out that the developed countries have played a role in intensifying the brain drain problem. The National Academy of Sciences of the USA, for example, has estimated that only one half of foreign nationals that obtain their Ph.D. in physics in the USA return to their home country. This is because the US Science Community has recognised that it can not meet the demands for physicists in the USA from its native-born Ph.D's. There has been much effort spent and numerous reports written stressing the desirability of getting as many as possible of the foreign nationals - and not only** from the developing countries - to stay.

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* It must be remarked that a part of the prosperity of South Korea is due to the returning expatriates who were trained in the US. One should not always be ungrateful.

** "If we capitalise the value of those who have left the British Isles for America since the war, we have very much more than paid back the whole of the Marshall Aid". - Lord Bowden.

iv) In this context, we would humbly like to suggest that (even if there is no governmental action on the part of the North's Aid Agencies- and there should be) the expatriates' feelings of indebtedness to their own societies for having educated them may at least partly be assuaged by suggesting to them to contribute to a (privately-run) Foundation for Science which may be set up by each developing country. Such Foundations for Science may receive donations, in cash or kind, from expatriate scientists, at least equivalent to the educational benefits they may have obtained from their own country - thus enriching their countries' scientific and educational system. (This should be done with a finesse and not in a ham-handed manner).

E) <u>The Role of Private Foundations for Science and Technology</u>

The role of private foundations (for all but the centrally-planned economies of the Second World) cannot be overstressed. There are 22,000 such foundations in the United States alone. Provision must be made for these foundations to receive generous government help in terms of taxation relief. (The role of private foundations is particularly important for the countries of the Middle East where once foundations for research and education were legion.* Today one may see private palaces being erected all over but hardly a Palace for Science).

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* This was testified to by Imam Ghazzali who paid a deserved tribute in the 11th century to the lands of Iraq and Iran when he said: "There are no countries in which it is easier for a scholar to make a provision for his children". This was at the time when he was planning to become a recluse and to cut himself off from the world. (See *Ideals and Realities*, Second Edition, p. 211).

F) Recognition that Creativity in Scientific Research is not Easy and that it has its own Mores and Modalities. (Appendix VI). Finally, it should be borne in mind that scientific research can not always deliver solutions to all the problems all the time, particularly to the time scale set by the administrators.* Witness, for example, the situation in the North, regarding SDI, or cancer, or AIDS research - this, in spite of the expenditures of billions of dollars in rich countries and the provision of hundreds of researchers. This must be kept in mind when making (what may be unreasonable) demands on the small and provisionless scientific communities and holding them to vindictive ransom (as has happened in some developing countries). It is also important to realise that in the end, it is the individual scientist and the technologist who is going to produce the new Idea.

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* One must remember that new and advanced technologies can not always be conjured up to order. In this context the following quote is relevant: "It is implicit in the thinking of many economists that new technologies arise essentially in response to the interaction of economic forces. This is, of course partly true. However, to rely on the 'technological fix' for the solution of difficulties which have reached crisis level can be exceedingly dangerous; the long lead time from discovery through development to application on a significant scale can easily mean that the solution comes too late. In contrast, new scientific discoveries increasingly make possible the development of completely new technologies which economic forces could never have conjured up". - Alexander King, President of the Club of Rome.

Two examples which immediately come to mind are those of the transistor versus thermionic tubes and quartz versus mechanical watches.

7. SCIENCE AND TECHNOLOGY EDUCATION POLICY

> "Unless it has its own scientists and technicians, no country can call itself free. This involves the whole problem of scientific and technical training from secondary education to fundamental research ..." - René Maheu, UNESCO Director General (1965).

Science Education lies* at the base of all these developments. It is imperative that we should take note of what is going on in this field. In the Table (Table IV) appended to this Section, I give the World Bank figures for educational enrolment for developing countries. (These figures unfortunately do not distinguish between Science and non-Science studies.)

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* The late Richard Feynman - perhaps the greatest physicist of my generation - related his talk with the Japanese Ambassador on the occasion of the ceremony for the award of the Nobel Prize to him in Sweden. "He was a very interesting man, and we got to talking. I had always been interested in how it is the different countries and different peoples develop differently. I told the Ambassador that there was one thing that always seemed to me to be a remarkable phenomenon: how Japan had developed itself so rapidly to become such a modern and important country in the world. 'What is the aspect and character of the Japanese people that made it possible for the Japanese to do that?' I asked. The Ambassador answered in a way I like to hear: 'I don't know,' he said. 'I might suppose something, but I don't know if it's true. The people of Japan believed they had only one way of moving up: to have their children educated more than they were; that it was very important for them to move out of their peasantry to become educated. So there has been a great energy in the family to encourage the children to do well in school and to be pushed forward. Because of this tendency to learn things all the time, new ideas from the outside world spread through the educational system very easily. Perhaps that is one of the reaons why Japan has advanced so rapidly'." (*Surely You Are Joking Mr. Feynman*, R. P. Feynman).

Table IV

Percentage of Age Group Enrolled in Education

		Primary (6 to 11 years of age)		Secondary (12 to 19 years of age)		Tertiary (20 to 24 years of age)	
		1965	1985	1965	1985	1965	1985
	Low income economies (GNP/Cap less than 400 US$)	74 w*	99 w	22 w	34 w	2 w	...
	China and India	83 w	110 w	25 w	37 w	2 w	...
	Other low - income	44 w	67 w	9 w	22 w	1 w	5 w
1	Ethiopia	11	36	2	12	0	1
2	Bhutan	7	25	0	4	...	0
3	Burkina Faso	12	32	1	5	0	1
4	Nepal	20	79	5	25	1	5
5	Bangladesh	49	60	13	18	1	5
6	Malawi	44	62	2	4	0	1
7	Zaire	70	98	5	57	0	2
8	Mali	24	23	4	7	0	1
9	Burma	71	102	15	24	1	...
10	Mozambique	37	84	3	7	0	0
11	Madagascar	65	121	8	36	1	5
12	Uganda	67	...	4	...	0	1
13	Burundi	26	53	1	4	0	1
14	Tanzania	32	72	2	3	0	0
15	Togo	55	95	5	21	0	2
16	Niger	11	28	1	6	...	1
17	Benin	34	65	3	20	0	2
18	Somalia	10	25	2	17	0	...
19	Central African Rep.	56	73	2	13	...	1
20	India	74	92	27	35	5	...
21	Rwanda	53	64	2	2	0	0
22	China P.R.	89	124	24	39	0	2
23	Kenya	54	94	4	20	0	1
24	Zambia	53	103	7	19	...	2
25	Sierra Leone	29	...	5	...	0	...
26	Sudan	29	49	4	19	1	2
27	Haiti	50	78	5	18	0	1
28	Pakistan	40	47	12	17	2	5
29	Lesotho	94	115	4	22	0	2
30	Ghana	69	66	13	39	1	2
31	Sri Lanka	93	103	35	63	2	5
32	Mauritania	13	...	1	...	...	...
33	Senegal	40	55	7	13	1	2
34	Afghanistan	16	...	2	..	0	...
35	Chad	34	38	1	6	...	0
36	Guinea	31	30	5	12	0	2
37	Kampuchea, Dem.	77	...	9	...	1	...
38	Lao PDR	40	91	2	19	0	1
39	Viet Nam	...	100	...	43	...	...
	Middle - Income economies	85 w	104 w	22 w	49 w	5 w	14 w
	Lower middle-income (GNP/Cap between 400 and 1600 US$)	75 w	104 w	16 w	42 w	4 w	13 w
40	Liberia	41	...	5	...	1	...
41	Yemen PDR	23	66	11	19	...	...
42	Indonesia	72	118	12	39	1	7
43	Yemen Arab Rep.	9	67	0	10	...	...
44	Philippines	113	106	41	65	19	38
45	Morocco	57	81	11	31	1	9
46	Bolivia	73	91	18	37	5	20
47	Zimbabwe	110	131	6	43	0	3
48	Nigeria	32	92	5	29	0	3
49	Dominican Rep.	87	124	12	50	2	...
50	Papua New Guinea	44	64	4	14	...	2
51	Cote d'Ivoire	60	78	6	20	0	3

w: weighted average.

		Primary (6 to 11 years of age)		Secondary (12 to 19 years of age)		Tertiary (20 to 24 years of age)	
		1965	1985	1965	1985	1965	1985
52	Honduras	80	102	10	36	1	10
53	Egypt Arab Rep.	75	85	26	62	7	23
54	Nicaragua	69	101	14	39	2	10
55	Thailand	78	97	14	30	2	20
56	El Salvador	82	70	17	24	2	14
57	Botswana	65	104	2	29	...	1
58	Jamaica	109	106	51	58	3	...
59	Cameroon	94	107	5	23	0	2
60	Guatemala	50	76	8	17	2	8
61	Congo, People's Rep.	114	...	10	...	1	...
62	Paraguay	102	101	13	31	4	10
63	Peru	99	122	25	65	8	24
64	Turkey	101	116	16	42	4	9
65	Tunisia	91	118	16	39	2	6
66	Ecuador	91	114	17	55	3	33
67	Mauritius	101	106	26	51	3	1
68	Colombia	84	117	17	50	3	13
69	Chile	124	109	34	69	6	16
70	Costa Rica	106	101	24	41	6	23
71	Jordan	95	99	38	79	2	37
72	Syrian Arab Rep.	78	108	28	61	8	17
73	Lebanon	106	...	26	...	14	...
	Upper middle-income	**97 w**	**105 w**	**29 w**	**57 w**	**7 w**	**16 w**
	(GNP/Cap between 1600 and 4000 US$)						
74	Brazil	108	104	16	35	2	11
75	Malaysia	90	99	28	53	2	6
76	South Africa	90	...	15	...	4	...
77	Mexico	92	115	17	55	4	16
78	Uruguay	106	110	44	70	8	32
79	Hungary	101	98	...	72	13	15
80	Poland	104	101	58	78	18	17
81	Portugal	84	112	42	47	5	13
82	Yugoslavia	106	96	65	82	13	20
83	Panama	102	105	34	59	7	26
84	Argentina	101	108	28	70	14	36
85	Korea Rep. of	101	96	35	94	6	32
86	Algeria	68	94	7	51	1	6
87	Venezuela	94	108	27	45	7	26
88	Gabon	134	123	11	25	...	4
89	Greece	110	106	49	86	10	21
90	Oman	...	89	...	32	...	1
91	Trinidad & Tobago	93	95	36	76	2	4
92	Israel	65	99	48	76	20	34
93	Hong Kong	103	105	29	69	5	13
94	Singapore	105	115	45	71	10	12
95	Iran, Islamic Rep.	63	112	18	46	2	5
96	Iraq	74	100	28	55	4	10
97	Romania	101	98	39	75	10	11
	Developing Countries	**78 w**	**101 w**	**22 w**	**39 w**	**3 w**	**8 w**
	Oil Exporters	**69 w**	**107 w**	**14 w**	**44 w**	**2 w**	**10 w**
	Exporters of manufactures	**86 w**	**109 w**	**27 w**	**40 w**	**3 w**	...
	Highly Indebted countries	**88 w**	**104 w**	**21 w**	**47 w**	**5 w**	**16 w**
	Sub-Saharan Africa	**41 w**	**75 w**	**4 w**	**23 w**	**0 w**	**2 w**
	High income oil exporters	**43 w**	**86 w**	**10 w**	**56 w**	**1 w**	**11 w**
98	Saudi Arabia	24	69	4	42	1	11
99	Kuwait	116	101	52	83	...	16
100	United Arab Emirates	...	99	...	58	0	8
101	Libya	78	127	14	87	1	11

w: weighted average.

Table IV

Percentage of Age Group Enrolled in Education

		Primary (6 to 11 years of age)		Secondary (12 to 19 years of age)		Tertiary (20 to 24 years of age)	
		1965	1985	1965	1985	1965	1985
	Industrial market economies (GNP/Cap higher than 4000 US$)	107 w	102 w	63 w	93 w	21 w	39 w
102	Spain	115	104	38	91	6	27
103	Ireland	108	100	51	96	12	22
104	New Zealand	106	106	75	85	15	35
105	Italy	112	98	47	75	11	26
106	United Kingdom	92	101	66	89	12	22
107	Belgium	109	95	75	96	15	31
108	Austria	106	99	52	79	9	27
109	Netherlands	104	95	61	102	17	31
110	France	134	114	56	96	18	30
111	Australia	99	106	62	95	16	28
112	Germany, Rep. of	...	96	...	74	9	30
113	Finland	92	104	76	102	11	33
114	Denmark	98	98	83	103	14	29
115	Japan	100	102	82	96	13	30
116	Sweden	95	98	62	83	13	38
117	Canada	105	105	56	103	26	55
118	Norway	97	97	64	97	11	31
119	United States	...	101	...	99	40	57
120	Switzerland	87	...	37	...	8	22
	Nonreporting nonmembers	102 w	105 w	66 w	92 w	27 w	21 w
121	Albania	92	97	33	69	8	7
122	Angola	39	93	5	13	0	1
123	Bulgaria	103	102	54	100	17	18
124	Cuba	121	105	23	85	3	21
125	Czechoslovakia	99	97	29	39	14	16
126	German Dem. Rep.	109	101	60	79	19	31
127	Korea, Dem. Rep.	...	...	...	...	...	...
128	Mongolia	98	105	66	88	8	26
129	USSR	103	106	72	99	...	21

w: weighted average.

Table IV

Weighted Percentage of Age Group Enrolled in Education, for males and females, by group of countries

	Primary (6 to11 years of age)				Secondary (12 to 19 years of age)				Tertiary (20 to 24 of age)	
	Males		Females		Males		Females		Totals	
	1965	1985	1965	1985	1965	1985	1965	1985	1965	1985
Low income economies	...	110	...	88	...	41	...	26	2	...
(GNP less than 400 US$)										
China and India	...	121	...	98	...	45	...	29	2	...
Other low - income	58	75	31	56	13	28	4	16	1	5
Middle - income economies	92	109	79	101	26	57	19	51	5	14
Lower middle-income	84	111	66	100	21	50	12	41	4	13
(GNP between 400 and										
1600 US$)										
Upper middle-income	100	108	93	102	31	66	26	63	7	16
(GNP between 1600 and										
4000 US$)										
Developing Countries	84	110	62	92	28	45	14	33	3	8
Oil Exporters	78	113	59	101	20	53	9	42	2	10
Exporters of manufactures	...	119	...	98	...	48	...	33	3	...
Highly indebted countries	91	108	84	99	23	57	20	57	5	16
Sub-Saharan Africa	52	85	31	67	6	26	2	14	0	2
High income oil exporters	60	82	25	69	15	55	5	41	1	11
Industrial market economies	107	101	106	101	65	91	61	92	21	39
(GNP higher than										
4000 US$)										
Other countries with an										
upper middle income	103	...	102	...	60	...	72	...	27	21

Note The above data refer to a variety of years, generally not more than two years distant from those specified, and are mostly from Unesco. However, disaggregated figures for males and females sometimes refer to a year earlier than that for overall totals.

The data on *primary* school enrollments are estimates of children of all ages enrolled in primary school. Figures are expressed as the ratio of pupils to the population of school-age children. While many countries consider primary school age to be 6 to 11 years, others do not. The differences in country practices in the ages and duration of schooling are reflected in the ratios given. For some countries with universal primary education, the gross enrollment ratios may exceed 100 percent, because some pupils are younger or older than the country's standard primary school age. The data on secondary school enrollments are calculated in the same manner, but again the definition of *secondary* school age differs among countries. It is most commonly considered to be 12 to 17 years. Late entry of more mature students as well as repetition and the phenomenon of *bunching* in final grades can influence these ratios.

The *tertiary* enrollment ratio is calculated by dividing the number of pupils enrolled in all post-secondary schools and universities by the population, age 20 to 24. Pupils attending vocational schools, adult education programmes two-year community colleges, and distance education centers (primarily correspondence courses) are included. The distribution of pupils across these different types of institutions varies among countries. The *youth* population, that is 20 to 24 years, is used as the denominator since it represents an average tertiary level cohort. While in higher income countries, youths aged 18 to 19 may be enrolled in a tertiary institution (and are included in the numerator), in developing and in many industrialized countries, many people older than 25 years are also enrolled in such an institution. These data and definitions come from Unesco.
The *summary measures* in this table are country enrollment rates weighted by each country's share in the aggregate population.

From: "World Development Report 1988", World Bank 1988.
Published for the World Bank Oxford University Press; 1988.

A) <u>General Education</u>

So far as general education is concerned, I strongly believe that scientific and technological studies should start as early as possible together with the teaching of the three R's and the instilling of a feeling for experimentation. (Of the three R's, the easiest to teach in my view is arithmetic - addition, subtraction and multiplication (but not division). Everyone must learn to count. Next comes reading, particularly readings from Science, the provision of which should be the responsibility of scientific communities as part of their fight to help create a favourable climate regarding Science among the general public).

B) <u>Secondary and Tertiary Education</u>

There are wide variations between the different countries, as well as between the industrialised and the developing countries. <u>The starkest variations, however, are in the average numbers we educate between the ages of 12-19 (secondary education)</u> and the ages between 20-24 (tertiary education). The low income developing country averages are particularly small compared with those of the developed countries (22% to 37% for the South on the average, versus 93% for the North for secondary education; and 5% for the South versus 39% for the North, for tertiary education). This means that at the earning stage, a student from the secondary level in most of our Southern countries is ill-equipped for the modern world.

C) <u>Secondary Education</u>

i) After a period of compulsory lower-secondary education* (which may finish at the age of 15 or 16) most modern societies provide for two parallel educational systems. Using the U.K. terminology of the 1970's, these two systems may be called (1) the system of "professional" education comprising technical, vocational, agricultural and commercial courses, and (2) the system of "liberal" education comprising courses which lead on to the university level, in the sciences, engineering, medicine and the arts.

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* At the secondary level, whereas in Japan, all science subjects are compulsory - in the USSR, even the future musicians or footballers or seamstresses must study physics, chemistry, mathematics and biology till they are sixteen - there is no such compulsion in most of our Southern countries' educational systems. We are too soft towards our students!

A major structural failing of the Third World educational system has been that, in general, no credible "professional" system has developed. It is true that a half-hearted system of polytechnic institutions and vocational schools has been built up in recent years in a number of Third World countries, but this system has had scant prestige attached to it. (As a general rule, such systems have been run by the Ministries of Labour and Employment, rather than the Ministries of Education).

ii) To see how inadequate such a system has been, one may recall that in industrialised countries the proportion of those enrolled for the two streams is of the order of 50:50. In the Third World, however, the proportion of the "professional" versus the "liberal" enrolment (at the secondary stage) is normally of the order of 10:90. This preponderance of the technologically illiterate is the major cause of unemployment and of the Third World's technological backwardness.

iii) One of the main educational tasks before the Third World is to change this ratio of 10:90 to 50:50. In the conditions of today, the "professional system" should be accorded equal status with the better known "liberal" educational system.

iv) Our first concern should be to bring a measure of prestige to the "professional" system of education. One will need to give serious consideration to the institution of National Certificates - or preferably, decide to identify these with the prevailing awards. What I have in mind is this. Parallel with the present "liberal" system of education, we should create a second - the "professional" system of education. Each award - the matriculation, or the intermediate, or the Bachelor's Degree (which comes at the climax of the secondary level, at the age of 19) - may be obtained either after the present "liberal" courses in arts or sciences (as now) or after technical, agricultural, or commercial courses from a polytechnic, an agricultural, or a commercial college. So far as job opportunities in administrative services are concerned, all matriculates or degree holders (from general, technical, or commercial streams) would count as equivalent. Only thus will the exclusive hold on the public mind in our countries of the present prestigious "liberal" system of education be broken.

D) University Education

i) The proportion of those following Science and Engineering versus those following the arts, at the "liberal" university level is of the order of 50:50 in most of the industrialized countries. This is certainly not the case for most developing countries. One must aim at a similar 50:50 ratio for the developing countries.* (This will need inter-alia equipping the laboratories and institutions of higher learning adequately).

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* In a recent report of the United Kingdom University Grants Commission (issued in 1984) the figure of 52 versus 48 per cent is cited as the present level of distribution for populations of scientists and technologists compared with art students.

ii) Specialisation

One proposal which may be considered in this context is that of specialisation. Could, for example, a consortium of Universities in the US and UK be helped by their Governments and encouraged to take care of University Science in all those developing countries which desire to be helped? Could the Netherlands and Belgium look after the building up of libraries and laboratories? Could Germany and Japan look after technical education at all levels? Could Scandinavia look after the scientific aspects of ecology? Could Switzerland and Austria (with their well-known pharmaceutical expertise) look after medical education? Could Italy with its experience of setting up International Centres in Physics and Biotechnology, look after the creation of similar institutions in all disciplines of science in concert with developing countries? Could the US, Canada, Australia and New Zealand look after education for agriculture and education for prospecting? Could one envisage the USSR taking care of primary, secondary and vocational education Third-World-wide? Could France, Canada and Spain carry out all these actions for the French and Spanish speaking developing countries if desired by them? This is merely an illustration of what a possible division of the relevant tasks could be. Eventually, of course, these suggestions would have to be tailored and modified when detailed projects are elaborated.

iii) What I have in mind is something patterned along the lines of the success which India achieved in the decade of the sixties when it created four new Indian Institutes of (Science and) Technology. The one in Kanpur was created by a US consortium of universities which helped to raise and furnish it, besides supplying the higher cadres of teaching staff for a number of years. The one in Delhi was helped by a consortium of British universities; the one in Bombay by the USSR and the one in Madras by the Federal Republic of Germany. Each nation helped to build up "its" institute under Indian auspices, contributed staff and left behind a tradition in teaching and research which has continued even after the original contracts have expired. There was a healthy rivalry between the donor nations vying with each other; this guaranteed the excellence and standards of quality. What I envisage in the proposal above is something like this except that it is to be carried out on a much wider canvas. One would hope that by the year 2000, if the plans are drawn up now, many of the objectives I have mentioned above will have been achieved. (In this, one must not forget that many Third World countries could make highly valued intellectual inputs to such specialised efforts even though not affluent enough to contribute materially).

8. INTERNATIONAL MODALITIES FOR THE GROWTH AND UTILISATION OF SCIENCE AND TECHNOLOGY

Recognition that the Growth of Science Education as well as Science and Technology Research is basically a Problem for the South and a Long-Term One. In the end, the growth of science and its utilisation by the South is a Southern problem, though outside help - particularly if it is organised - can make a crucial difference. The modalities for growth and utilisation of science and technology entail two types of actions: those needed to be adopted in and by the South and those that need to be carried out in concert with the North. *

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* It has been one's general experience , that whereas scientific communities in the North are quite generous in accepting trainees for research and in helping to build up corresponding communities in developing countries, the same can not be said for technologists. (This is understandable in view of the fact that technology provides the visible raison for better standards of living of the industrialised countries. One can not blame the North for not wanting to part with such an advantage lightly). Accepting this, it is important that the aid asked for by the Third World is more in terms of "science transfer" rather than "technology transfer".

A) Concerted Action between the South and the North. We list here some of the modalities through which the North may help the South to build up its scientific base.

i) 10% of the Aid Funds to be earmarked for Science and Technology.* The linking of the aid for Science and Technology with the total bilateral aid from the North is an important political modality. It should come to be established (principally through the type of requests made by the South, as well as the favourable reception to such requests by the North), that 10 per cent of the aid given by every developed country is to be spent to enhance Science and Technology in the Third World.

ii) Birthright of Southern Scientific Communities: Free Access to Scientific Literature. It should be considered as part of a birthright of scientific communities in a developing country that the country should have at least one complete Central Science Library containing most of the scientific and technological journals and all scientific books.** Arrangements (by the Aid Organisations or the World Bank) should be made with publishers in the North so that scientific books and journals are made available at a fraction of their present price - at least one copy for each country - and sent to a designated Central Library in at least fifty (in our count) of the developing countries, which can immediately make use of this literature.

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* This would amount to some $3.5 billions. $3.5 billion (in foreign currencies) for Southern Science and Technology would make up (together with the domestic $14.5 billion, argued for, earlier in Section 6B) a total of $18 billion. This would constitute some 10% of the world's spending on Science and High Technology. Even though small - this could - without doubt - transform the South.

** "I consider that the scientific profession is grossly exploited by commercial publishers, both of books and of journals and that it is necessary to reverse this trend by arranging that cooperative associations of scientists such as the numerous learned societies, should be able to publish without excessive mark-ups". - Alan L. Mackay F.R.S., Professor of Crystallography, Birkbeck College, University of London. (See Appendix XII).

Equity demands that scientific literature should be exempted from the Uruguay Round so far as the poorer developing countries are concerned.

iii) United Nations Agencies (including the World Bank) to help create International Centres for Science and Technology. (Appendices I, II, III and IV). The United Nations agencies - including the United Nations University - should play a prominent role in building up scientific infrastructure in their areas of competence. Developing countries need international research institutions on the applied side like the Wheat and Rice Research Institutes in Mexico and the Philippines (see the note on CGIAR, Appendix IV) and the International Centre for Insect Physiology and Ecology in Kenya. There is also the experience on the basics side, of IAEA and UNESCO (with generous Italian support) in relation to the International Centre for Theoretical Physics, Trieste (with visits of 4114 physicists during 1988 - 2220 of them from developing countries and 1894 from the industrialised countries), or, of UNIDO for the International Centre for Biotechnology and Genetic Engineering, at Trieste and Delhi. These Centres are run by the scientists for the scientists. The South should, at the least, ensure proper utilisation of those trained at these Centres and urge other United Nations Organisations to set up international centres training for research in disciplines relevant to their competence.

iv) Three New International Centres

In this context, there is the proposal to create in Trieste an International Centre for Science which will have five components 1) the existing International Centre for Theoretical Physics; 2) the existing local International Centre for Genetic Engineering and Biotechnology; 3) a new International Centre for High Technology and New Materials; 4) a new International Centre for Chemistry, Pure and Applied; and finally, 5) a new International Centre for Earth Sciences and the Environment. The

International Centre for Science has been projected with United Nations sponsorship.

B) <u>South-South Collaboration.</u>* South-South collaboration in Science and Technology is important for Scientific and Technological Education, for Higher Training, for Sciences in Application and for building up of Technology. This is because of similarity of the problems and the experiences.**

Some of these ideas are elaborated below.

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* South-South Collaboration is important but one must not forget that Science and Technology are being created mostly in the North or in Japan. Thus, it would be counterproductive to speak of South-South collaboration in this area to the exclusion of South-North collaboration.

** Whereas at present one knows all about the scientific establishments and the organisations which exist in the developed countries, one has very little knowledge of what facilities are available for scientific training and research in the developing world. This needs to be rectified as a top priority.

i) The Third World Academy of Sciences (TWAS), which started operation during 1985 and which has as its Fellows (or Associate Fellows) 199 most prestigious scientists from 50 countries - nine of these being (all) the living Science Nobel Laureates born in the Third World - has among its projects one for South-South collaboration in Sciences. More than two hundred grants have so far been made available by the Scientific Institutions in Argentina, Brazil, Chile, China, Colombia, Ghana, India, Iran, Kenya, Madagascar, Mexico, Vietnam and Zaire for hospitating such visits. The Third World Academy of Sciences pays for the travel of Third World scientists to a Third World country. Clearly, the efforts of TWAS - a humble non-governmental organisation - need to be enhanced a hundred fold.

ii) The Third World Academy of Sciences convened in October 1988 the first meeting of a new Third World Network of Scientific Organisations (TWNSO). This initiative is the scientific analogue of the Founding of the Group of 77 since the Network now has membership from 96 scientific organisations, including 25 Ministers of Science and Higher Education. This new initiative needs more than political support from the South (see the Trieste Declaration on page 15). The discussions at the TWNSO Forum focussed on the need to consider Third World joint action on global scientific problems like the Greenhouse Effect, Hazards of Waste Disposal in the South, the Ozone Layer, the Human Genome problem and Fusion Research.

iii) South-South collaboration of scientists takes place automatically at International Centres, for example, at the International Centre for Theoretical Physics, where, during the last 24 years, there have been 18,000 visits of developing country physicists who have met and have had the opportunity to collaborate with each other. (Even for the larger countries like India and China, scientists from different parts of the country hardly meet except in the international locations). What is urgently needed is provision of funds for carrying on this collaboration <u>after</u> the physicists have left the Centre.

iv) Another possibility of South-South collaboration arises through the possible joint programmes for Higher Technological Education. For example, the Indian Institutes of (Science and) Technology would, I am sure, be even more responsive to the needs of the whole South, if they were mandated to do so.

9. A FIVE-YEAR BLUEPRINT FOR SCIENCE AND TECHNOLOGY IN THE DEVELOPING WORLD.

A) If one were charged with running Science in a typical developing country of modest size,* one would, in the first place:

1) Carry through the recommendations regarding general science education as well as secondary and tertiary education in respect of Science and Technology reforms discussed on pages 65 - 68 of paragraph 7;

2) Build up Basic Scientific and Technological research in the universities, by appropriate training of cadres of scientists and technicians so as to assure a critical size, while maintaining international contacts.

3) Build up at the same time expertise in "Classical" Low Technologies emphasising craftsmanhip and fabrication techniques;

4) One would commission and blue-print a comprehensive plan for Applied Sciences. (What one develops first, depends on a nation's priorities and could be in one or more of the following areas: agriculture, health, livestock, energy, local materials and minerals, environment, soil sciences, oceans, communications).

5) Finally, one would concentrate on training of personnel for Research and Development in the area of <u>Science-based high technology as the quickest way to produce wealth</u>.

B) On Basic and Applied Sciences and Science-based "High" Technology, one would spend 4%, 4% and 8% of the educational budget respectively. (See Table V).

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* Naturally, if a developing country possesses considerable scientific communities and infrastructure, the timings in this blueprint would have to be changed.

Table V

Comparative Expenditure on Science and Technology versus Proposed Funding for Science and High Technology (16% of the Education Budget) by country.

Developed Market Economy Countries

	COUNTRY	POPULATION (x 1,000)	GNP/CAPITA (US$)	DEFENCE % of GNP	HEALTH % of GNP	EDUC. % of GNP	SCIENCE AND TECHNOLOGY* ACTUAL EXPENDITURE (Millions US$)	16% of EDUC. BUDGET (Millions US$)
1	Iceland	241	10,720	n.a.	6.80	3.50	20.6	19
2	Luxembourg	366	13,380	0.80	0.80	5.65	n.a.	46
3	New Zealand	3,246	7,310	1.90	4.90	4.40	214	184
4	Ireland	3,560	4,840	1.80	7.05	6.70	155	194
5	Norway	4,144	13,890	2.90	6.40	6.80	921	643
6	Israel	4,296	4,920	27.10	3.50	8.40	528	320
7	Finland	4,919	10,870	1.50	5.30	5.50	802	484
8	Denmark	5,101	11,240	2.40	5.80	6.50	688	614
9	Switzerland	6,421	16,380	2.20	5.60	5.00	2,313	828
10	Austria	7,545	9,150	1.20	4.60	5.80	828	648
11	Sweden	8,330	11,890	3.10	9.10	8.00	2,575	1,329
12	Belgium	9,853	8,450	3.10	5.90	5.90	1,166	810
13	Greece	9,937	3,550	7.20	3.60	2.40	71	161
14	Portugal	10,198	1,970	3.50	3.00	4.80	80	182
15	Netherlands	14,486	9,180	3.20	6.70	7.00	2,660	1,504
16	Australia	15,789	10,840	3.20	5.20	6.00	1,880	1,712
17	Canada	25,414	13,670	2.30	6.40	7.40	4,863	3,954
18	South Africa	32,432	2,010	4.00	0.50	2.70	n.a.	360
19	Spain	38,730	4,360	2.40	4.60	2.50	844	736
20	France	55,133	9,550	4.10	6.70	5.30	9,477	4,721
21	United Kingdom	56,539	8,390	5.40	5.40	5.10	9,962	4,041
22	Italy	56,945	6,520	2.70	5.90	5.60	4,084	3,554
23	Germany Fed. Rep.	61,065	10,940	3.30	8.10	4.60	16,701	4,952
24	Japan	120,579	11,330	1.00	4.60	5.10	35,520	10,168
25	United States	238,780	16,400	6.40	4.30	5.00	101,818	29,203

* Note that for Science and Technology, Ireland, Greece and Portugal - the poorest of the "rich" countries - are spending less than 16% of their Education Expenditures.

(Desirable expenditures on classical "Low" Technology are not shown in these tables.)

Table V

SOCIALIST COUNTRIES

	COUNTRY	POPULATION (x 1,000)	GNP/CAPITA (US$)	DEFENCE % of GNP	HEALTH % of GNP	EDUC. % of GNP	SCIENCE AND TECHNOLOGY ACTUAL EXPENDITURE (Millions US$)	16% of EDUC. BUDGET (Millions US$
1	Albania	2,943	n.a.	4.40	2.60	3.00	n.a.	23
2	Mongolia	1,909	n.a.	10.50	1.40	5.00	n.a.	15
3	Bulgaria	8,980	n.a.	4.00	4.00	6.20	1,429	448
4	Hungary	10,660	n.a.	2.20	2.80	5.00	1,413	500
5	Czechoslovakia	15,497	n.a.	4.00	5.20	5.20	3,533	809
6	German Dem. Rep	16,716	n.a.	4.90	2.90	4.50	5,099	964
7	Korea Dem. Rep.	20,357	n.a	10.20	0.90	3.20	n.a.	115
8	Romania	22,866	n.a.	1.40	2.00	2.00	145	260
9	Poland	37,288	2,120	2.50	3.90	3.90	949	1,054
10	Vietnam	61,640	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
11	USSR	277,563	n.a.	11.50	3.20	4.70	85,054	14,688
12	China P.R.	1,041,094	310	7.00	1.40	2.80	n.a.	1,395

Table V

DEVELOPING COUNTRIES - Populations up to nearly 3 millions

	COUNTRY	POPULATION (x 1,000)	GNP/CAPITA (US$)	DEFENCE % of GNP	HEALTH % of GNP	EDUC. % of GNP	SCIENCE AND TECHNOLOGY % GNP	SCIENCE AND TECHNOLOGY Actual Expenditure (Millions US$)	16%* of EDUC. BUDGET (Millions US$)
1	Brunei Darussalam	294	17,580	7.90	0.70	2.00	n.a.	n.a.	12
2	Qatar	320	15,980	5.80	n.a.	4.90	n.a.	n.a.	44
3	Bahrain	423	9,560	3.60	2.20	3.30	n.a.	n.a.	25
4	Cyprus	660	3,790	2.40	1.90	3.80	0.1	2.5	15
5	Fiji	702	1,700	1.20	2.70	6.60	n.a.	n.a.	13
6	Gambia	737	230	2.10	3.00	4.40	n.a.	n.a.	1
7	Swaziland	758	650	1.50	1.80	5.80	n.a.	n.a.	6
8	Guyana	806	570	4.80	3.80	7.40	0.2	1	5
9	Guinea Bissau	886	170	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
10	Gabon	997	3,340	2.10	1.3	4.20	n.a.	n.a.	24
11	Mauritius	1,036	1,070	0.30	2.20	4.20	0.2	2.2	7
12	Botswana	1,070	840	3.30	2.30	8.40	0.2 (1975)	1.8	12
13	Oman	1,181	7,080	27.70	2.30	3.70	n.a.	n.a.	44
14	Trinidad & Tobago	1,187	6,010	1.00	1.80	6.00	0.8	57	72
15	United Arab Em.	1,381	19,120	7.40	1.00	1.80	n.a.	n.a.	73
16	Lesotho	1,515	480	2.90	1.30	3.30	n.a.	n.a.	4
17	Mauritania	1,693	410	6.60	1.31	7.33	n.a.	n.a.	8
18	Kuwait	1,736	14,270	5.30	2.40	4.20	0.9	223	182
19	Congo	1,872	1,020	2.60	1.40	5.40	n.a.	n.a.	18
20	Yemen PDR	2,086	540	17.00	n.a.	7.00	n.a.	n.a.	12
21	Panama	2,180	2,020	2.10	6.30	5.30	0.2 (1975)	8.8	35
22	Liberia	2,196	470	2.60	1.80	4.50	n.a.	n.a.	7
23	Jamaica	2,227	940	1.40	3.50	6.40	0.1(1975)	2.1	31
24	Singapore	2,557	7,420	5.70	1.60	5.30	0.5	94.8	158
25	Central African Rep.	2,583	270	2.00	1.10	5.40	0.2	1.5	6
26	Costa Rica	2,593	1,290	0.00	1.44	6.00	0.1	3.3	33

* These are the desirable figures for Science and (Science - based) High Technology alone.
Expenditure on classical "Low" Technology, (which, according to the Third World Academy of Sciences (TWAS) estimates, should minimally amount to another 8% of the educational budgets) are not shown explicitly.

Table V

DEVELOPING COUNTRIES - Populations from 3 to 10 millions

	COUNTRY	POPULATION (x 1,000)	GNP/CAPITA (US$)	DEFENCE % of GNP	HEALTH % of GNP	EDUC. % of GNP	SCIENCE AND TECHNOLOGY % GNP	SCIENCE AND TECHNOLOGY Actual Expenditure (Millions US$)	16% of EDUC. BUDGET (Millions US$)
27	Uruguay	3,004	1,660	2.90	0.90	2.40	0.2(1975)	10	30
28	Togo	3,038	250	2.50	2.20	6.20	1.4(1975)	10.6	7
29	Nicaragua	3,263	850	12.40	4.60	6.00	0.3	8.3	31
30	Lebanon	3,301	1,833	7.30	1.20	5.80	n.a.	n.a.	55
31	Paraguay	3,388	940	1.20	0.60	1.60	0.2 (1975)	6.3	10
32	Papua New Guinea	3,499	710	1.70	3.20	6.90	n.a.	n.a.	27
33	Jordan	3,512	1,560	14.10	1.70	7.80	2 (1980)	54.8	49
34	Libyan A. Jamahiriya	3,600	7,500	12.90	1.30	3.70	0.2 (1982)	45	169
35	Sierra Leone	3,745	370	0.70	1.10	2.60	n.a.	n.a.	7
36	Benin	4,043	270	2.30	1.40	5.00	n.a.	n.a.	8
37	Honduras	4,396	730	5.30	1.70	4.00	n.a.	n.a.	136
38	Burundi	4,696	240	3.50	0.80	3.40	0.4	4.5	6
39	Chad	4,982	n.a.	10.40	0.70	1.80	0.3(1975)	1.8	1
40	Somalia	5,384	270	10.00	0.60	1.60	n.a.	n.a.	6
41	Haiti	5,451	350	1.60	1.00	1.20	n.a.	n.a.	3
42	El Salvador	5,564	710	5.10	1.50	3.00	0.9	35.5	19
43	Rwanda	6,026	290	1.50	0.60	3.10	0.1	4.9	8
44	Guinea	6,049	320	3.10	1.20	3.30	n.a.	n.a.	10
45	Dominican Rep.	6,261	810	1.20	1.40	2.00	n.a.	n.a.	20
46	Bolivia	6,383	470	2.60	1.50	4.90	n.a.	n.a.	20
47	Niger	6,391	200	0.80	1.00	2.90	0.1(1975)	1.5	7
48	Senegal	6,558	370	2.80	1.30	4.90	1(1975)	24	19
49	Zambia	6,640	400	4.10	2.10	5.40	0.5(1975)	13.3	29
50	Malawi	7,044	170	1.70	2.30	2.60	0.2(1975)	2.4	5
51	Tunisia	7,143	1,220	5.60	2.60	5.80	n.a.	n.a.	83
52	Mali	7,511	140	4.90	1.50	3.30	n.a.	n.a.	6
53	Burkina Faso	7,885	140	2.70	0.80	2.70	0.5(1975)	5.5	4
54	Yemen Arab Rep.	7,955	520	17.60	1.70	7.00	0.3(1975)	12.4	46
55	Guatemala	7,966	1,240	2.90	0.90	1.80	0.5	49.4	26
56	Zimbabwe	8,406	650	6.20	2.20	7.50	n.a.	n.a.	79
57	Angola	8,756	n.a.	14.20	1.20	5.20	n.a.	n.a.	58
58	Ecuador	9,367	1,160	1.60	1.10	4.10	0.4(1975)	43.50	87

Table V

DEVELOPING COUNTRIES - Populations from 10 to 20 millions

	COUNTRY	POPULATION (x 1,000)	GNP/CAPITA (US$)	DEFENCE % of GNP	HEALTH % of GNP	EDUC. % of GNP	SCIENCE AND TECHNOLOGY % GNP	SCIENCE AND TECHNOLOGY Actual Expenditure (Millions US$)	16% of EDUC. BUDGET (Millions US$)
59	Côte d'Ivoire	10,072	620	1.20	1.30	5.00	0.3(1975)	18.7	52
60	Cuba	10,097	1,852	7.10	3.40	6.30	0.7	130.9	193
61	Cameroon	10,191	810	2.00	1.00	3.50	0.8(1988)	49.5	48
62	Madagascar	10,312	250	2.40	2.20	3.80	0.20(1980)	5.1	17
63	Syrian Arab Rep.	10,483	1,630	16.60	0.40	6.10	n.a.	n.a.	161
64	Saudi Arabia	11,521	8,860	21.70	3.10	7.80	n.a.	n.a.	1299
65	Chile	11,990	1,440	4.20	2.70	4.80	0.4(1980)	68.50	172
66	Ghana	12,710	390	0.60	0.80	1.50	0.9(1975)	44.6	15
67	Uganda	15,474	n.a.	1.10	0.20	1.30	n.a.	n.a.	13
68	Malaysia	15,611	2,050	5.60	1.20	6.10	n.a.	n.a.	309
69	Iraq	15,654	1,861	50.00	0.80	3.40	0.1(1975)	27	152
70	Sri Lanka	16,143	370	1.70	1.30	2.80	0.2	11.9	29
71	Nepal	16,527	160	1.30	0.80	2.70	n.a.	n.a.	11
72	Venezuela	17,323	3,110	1.60	2.00	6.20	0.4	215	629
73	Mozambique	17,791	n.a.	4.80	0.80	1.90	n.a.	n.a.	17
74	Peru	18,653	960	6.90	1.10	2.90	0.2	35.8	95

Table V

DEVELOPING COUNTRIES - Populations from 20 to 50 millions

	COUNTRY	POPULATION (x 1,000)	GNP/CAPITA (US$)	DEFENCE % of GNP	HEALTH % of GNP	EDUC. % of GNP	SCIENCE AND TECHNOLOGY % GNP	SCIENCE AND TECHNOLOGY Actual Expenditure (Millions US$)	16% of EDUC. BUDGET (Millions US$
75	Kenya	20,375	290	4.10	2.10	6.00	0.8(1975)	47.2	61
76	Algeria	21,865	2,530	1.80	1.40	4.70	0.3(1975)	165.9	401
77	Morocco	21,924	610	5.60	1.00	7.20	n.a.	n.a.	156
78	Sudan	21,931	330	3.30	0.20	4.70	0.2(1980)	26.7	66
79	United Rep. Tanzania	22,242	270	3.30	1.40	3.30	n.a.	n.a.	37
80	Yugoslavia	23,100	2,070	3.70	4.10	3.50	n.a.	382	381
81	Colombia	28,418	1,320	1.40	0.80	3.10	0.1	37.5	230
82	Argentina	30,531	2,130	2.50	1.40	4.15	0.5(1980)	325	483
83	Zaire	30,557	170	1.20	0.40	3.50	n.a.	n.a.	48
84	Burma	36,831	190	3.60	1.00	2.00	n.a.	n.a.	21
85	Korea Rep.	40,646	2,180	5.40	0.30	4.80	1.1	886	654
86	Ethiopia	42,271	110	9.30	1.40	3.00	n.a.	n.a.	22
87	Iran Islamic Rep.	45,160	1,778	13.30	1.60	7.50	0.5(1975)	401.4	966
88	Egypt Arab Rep.	47,108	710	8.50	1.20	4.30	0.2	67	236
89	Turkey	49,406	1,130	4.80	0.60	3.30	0.6(1980)	335	n.a.

Table V

DEVELOPING COUNTRIES - Populations from 50 to over 100 millions

	COUNTRY	POPULATION (x 1,000)	GNP/CAPITA (US$)	DEFENCE % of GNP	HEALTH % of GNP	EDUC. % of GNP	SCIENCE AND TECHNOLOGY % GNP	Actual Expenditure (Millions US$)	16% of EDUC. BUDGET (Millions US$
90	Thailand	50,950	830	4.00	1.10	4.10	0.3	126.80	268
91	Philippines	54,725	600	1.80	0.70	1.80	0.2	65.67	91
92	Mexico	78,820	2,080	0.70	0.40	2.60	0.6	983.6	985
93	Pakistan	94,933	380	6.00	0.40	1.80	0.2(1980)	72.1	109
94	Nigeria	99,669	760	1.80	0.60	2.00	0.3(1980)	227.2	241
95	Bangladesh	100,592	150	1.70	0.40	1.80	0.2(1975)	30.2	43
96	Brazil	135,539	1,640	0.80	1.60	4.00	0.6	1,333.7	1,242
97	Indonesia	162,212	530	3.90	0.60	3.40	0.3	257.9	549
98	India	765,147	250	3.20	0.90	3.10	0.9	1,721	1,004

In the population range of 20 millions upwards, it is to be noted that Argentina, the Republic of Korea, Turkey, Mexico, Brazil and India are the only countries where the actual science expenditures are higher than 16% of their education budgets – the desirable minimum for developing countries recommended by TWAS (Third World Academy of Sciences).

Population and GNP/Capita figures are from "World Bank Atlas 1987" and refer to 1985; Defence, Health and Education figures are from "World Military & Social Expenditures 1987-88" and refer to 1984; Science (% of GNP and Expenditure) are from "UNESCO Statistical Digest 1987" and generally refer to 1984 or 1985 - the tables show the year referred to when no figures for 1984 or 1985 are available.

What should be spent on training and development in the "Low" Technology area? The answer is clearly as much as one may afford.

One minimal figure which has been suggested in this context is worth repeating. It is UNESCO's (United Nations Educational, Scientific and Cultural Organisation) famous 1% of GNP for all Sciences ("Basic" and "Applied") plus all Technology (Classical ("Low") as well as "High"). On the average basis of 4% of GNP being spent on education by the South, this roughly works out at 1/6:1/6:1/3:1/3: of 1% of GNP for Sciences "Basic" versus "Applied" Sciences versus Classical ("Low") Technology versus "High" Technology.

C) Where would one get the initial necessary training? Clearly, here, one would have to rely on the universities and the institutes in the North (or on South-South collaborative programmes) for providing the training facilities in the first place. *

For Basic Sciences, one may also think of the IAEA- and UNESCO-run International Centre for Theoretical Physics (ICTP) (See Appendix I) or the UNIDO-run International Centres for Genetic Engineering and Biotechnology (ICGEB) (or the International Centre for Science (ICS) with its three projected new components, the International Centre for Earth Sciences and the Environment, the International Centre for Chemistry, Pure and Applied, and the International Centre for High Technology and New Materials (see page 73).

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* The reliance on foreign help for training of one's scientists and technicians should diminish as indigenous trained personnel becomes available and is utilised for this purpose.

D) For Applied Sciences (for example. agriculture) one would think of centres comprising the CGIAR Network, with the training component of these Centres emphasised. (See Appendix IV). There are three centres devoted to research on tropical agriculture (in Colombia, India and Nigeria) a fourth (in Syria) concentrating on agriculture in arid zones, a fifth (in the Philippines) on cross-breeding of rice, and three on genetic improvement of cattle (in Ethiopia, Kenya and the Ivory Coast) plus the International Centre for the Potato (in Peru). In addition, there is the Centre (in Rome) for the conservation of genetic resources, one (in Holland) for the fostering of rural agricultural cooperation, a twelfth (in Washington, D.C.) for the study of nutrition, and, finally, the world-famous Wheat Institute (CIMMYT) (in Mexico City).

This group of 13 institutes commands a total of $250 million from the World Bank. There is the hope that a similar set of regional institutions may be created (in three to five years) for High Technology and for the Earth's Environment - with a similar measure of funding by the World Bank and other donor governments.*

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* It is important to realise that the CGIAR institutes, emphasising inputs of pesticides, insecticides and fertilisers, represent the discipline of Chemistry which, in this sense, is a survival science. Once Physics and High Technology are emphasised by the World Bank - in the new network here proposed - one will be moving on to sciences which are also wealth-producing. It is this type of altered perception about the Third World which we desperately need.

10. DESIRABLE REGIONAL ARRANGEMENTS AND GLOBAL SCIENCE

i) Leaving aside Luxembourg, Iceland and Malta (with populations of less than 1 million inhabitants) the minimum population for a Developed Market Economy country is 3.2 millions (for New Zealand). Of the developing countries, 10 have less than one million inhabitants; 16 have populations which range between 1 and nearly 3 millions, while 32 developing countries have populations ranging between 3 millions and 10 millions. (Above 10 millions there are 44 developing countries of moderate sizes - this includes the Asian socialist countries).

ii) We feel that it would be desirable if the richer of the developing countries like Brunei, Qatar, Kuwait, United Arab Emirates and others, which fall into the first category, would set up foundations for Science and Technology to help other Third World countries towards setting up Regional Centres for High Technology and Environment. These smaller but richer of the developing countries would also be excellent sites for United Nations-run International Centres (See Section 8), acting as modern "Athenses" of the developing world.*

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* When the thirteen members of OPEC raised oil prices, the South suffered equally as the North. Notwithstanding this, the South applauded what OPEC had done. One may have hoped reciprocally that at least a provision for the enhancement of the South's Science and Technology would be made by the OPEC Fund, for the entire Third World (as the then President of Venezuela urged the OPEC Fund to do in 1980). This, unfortunately, has not been happened. Can one hope that this may be achieved now?

iii) Clearly the countries in the first category, (that is, with populations between 1 and 3 millions), are too small to set up independent institutions for Science and Technology. <u>They will need linking with neighbouring countries with similar problems</u>. This cannot be spelt out in any detail here because the possibilities depend on the local circumstances.

iv) Among the second category of countries with populations of between 3 and 10 millions, it is interesting to note that Switzerland (with a population base of 6.4 millions) is a world leader in pharmaceuticals, specialised engineering and high technology. If there is the will, there is every possibility for Third World countries belonging to this second category to emulate the Swiss example in time.

v) The South must play an appropriate role in the area of Global Science, like the Global Change Programmes of ICSU, the UNESCO Programmes relating to the Biosphere, the management of the Antarctica, or, as pointed out by the Third World Network of Scientific Organisations (TWNSO), the more highly technological programmes of the IAEA in respect of Fusion and (for some of the more advanced developing countries) the Human Genome problem plus Space Sciences. It should be pointed out that both the North and the South are currently engaged in wrecking the environment. By playing its appropriate role in the global programmes for rectifying this, the South can make a distinctive contribution of great significance to the solution of this problématique. The possibilities offered, contribute one fruitful area of mutual cooperation between the South and the North.

11. **ENVOI**

In this note, we have pleaded that political action is needed in order to build up and utilise the so-far neglected community of its own scientists and technologists, by the developing world. Their numbers need to be multiplied so that they constitute a critical size; they have to be given proper recognition, provided with scientific literature and infrastructure, international contacts and provisions for their work and guaranteed tolerance by those who run our countries.* They may be ill-prepared at the present for taking on the developmental role but with careful nurturing and proper trust, they surely have the capability of transforming the South.**

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* In a recent College on Biophysics held at the International Centre for Theoretical Physics, a Brazilian scientist (who won the Centre's prestigious Heisenberg Prize) listed the following items for success with his research work in Brazil: 1) Imagination; 2) Hard Work; 3) Provision of Equipment; 4) Contact with Scientists of Developed Countries; 5) Inter-disciplinarity (particularly necessary for his subject, of Biophysics).

** As their colleagues have done in the North! There is no question but that our present world is a creation of modern science in application. We tend to forget that it was the Science of Physics in application, which brought about the modern Communications Revolution and gave a real meaning to the concept of One World and its mutual interdependence. We tend to forget that it was the Science of Medicine which brought about the Penicillin Revolution, leading to the present level of world population. We tend to forget that it were the Sciences of Chemistry and Genetics in application, which brought about the Fertilisers and the Green Revolutions, to feed part of this population. And we tend to forget that it is to these same sciences - the wealth-producing sciences of physics and geophysics, and the survival sciences of medicine, molecular biology, cell culture and chemistry - to which the Third World has to turn and is turning for resolution of some of its current problems. (Only its own nationals and its own facilities are not being utilised).

Judging from the actual versus desirable levels of educational and science expenditures, it is clear that while Latin American as well as the Confucian-Belt and some other Asian countries are indeed taking steps to enhance their scientific and technological communities, the African, the Arab, and the Islamic countries* by and large have a long leeway** to make up. There appears scant future for Science and Technology in these societies.

PARTICULARLY IF THE TRYST WITH THE YEAR 2000 IS TO BE KEPT.

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* According to the Institute of Scientific Information (ISI), it seems there were a total of 352,000 scientific authors in 1976, of which the Third World contributed 19,000. The Islamic countries as a whole (which should have contributed one quarter of the Third World) had 3,300 authors. (Israel alone had approximately 6,100).

** I have been wondering why Europe should be uniformly good at Science and Technology. Even a country as little known for scientific achievement as Bulgaria can produce first-class mathematicians if it puts its mind to it. (This is evidenced by the Bulgarian mathematicians who come to the ICTP). It seems to me the answer lies in that one must treat all of Europe as a cultural entity. If one member of the cultural entity is good in Sciences, it seems that all members of the same cultural unit can be, if they take courage from the example.

If this be a social law, then it would seem to me that it is important that at least one member of the African or Arab or Islamic cultural communities should make every effort to acquire first-class expertise in at least one of the Sciences. This will then break the psychological barrier and all members of such communities should be able to produce great Science if they set their minds to it. In this context, it is important that the advanced and the not so-advanced members of the same cultural community cooperate with each other.

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These notes were written for the South Commission meetings. I wish to acknowledge the discussions and the inspiration given to me in the affectionate atmosphere of the Commission generated by its Chairman, President J. Nyerere and its Secretary General, Dr. Manmohan Singh and his devoted staff.

I wish to thank all the members of the Commission and, in particular, the members of the Working Party on Science and Technology, Commissioners A. Ferrer, E. Navarrete, A. Papic, Marie-Angelique Savane, Ambassador Amir Habib Jamal, Mr. P. Bifani, Mr. C. Fortin and Mr. B. Gosovic, who attended the meeting which was held in Trieste from 24-26 November 1988 and, in addition, Commissioners Abdlatif Al-Hamad, Gamani Corea, Devaki Jain, Shridath Ramphal and Tan Sri Ghazali Shafie, whose critical remarks were invaluable. Commissioner Michael Manley (Prime Minister of Jamaica) contributed, particularly about secondary education.

The visit of Commissioner Carlos Andres Perez (President of Venezuela) to the Trieste Centre, as the first public act of a newly-elected President, and his renewed pledge to increase the spending on Science and Technology in Venezuela to 2% of GNP during the next five years, was a heartening manifestation of his personal interest.

Some of the footnotes and the appendices - which are a crucial part of the present text - have been added later, after the South Commission's draft was sent to the Press.

For the second edition, the major change is that *A Five Year Blueprint for Science and Technology in the Third World* is now the subject of a separate section (Section 9).

Note about the author

Commissioner Abdus Salam is member of the South Commission; Professor at Imperial College of Science and Technology, London; founder Director of the International Centre for Theoretical Physics, Trieste; President of the Third World Academy of Sciences and of the Third World Network of Scientific Organisations. He shared the Nobel Prize in 1979 for his research in uniting the electromagnetic and weak nuclear forces and for predicting the W and the Z particles.

THE INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

Note by
Dr. A.M. Hamende
Scientific Information Officer

1. Objectives

The International Centre for Theoretical Physics is a multi-disciplinary institution for research and training-for-research. It was founded in 1964 and is part of the International Atomic Energy Agency (Vienna) and of UNESCO (Paris). Professor Abdus Salam, Nobel Laureate for Physics in 1979, suggested the Centre's creation. Its annual regular budget is 16.6 million US$, ninety percent of which comes from the Government of Italy while IAEA and UNESCO contribute for the remainder.

The ICTP was created in view of reaching several objectives which are:

(a) to help in fostering the growth of advanced studies and research in physical and mathematical sciences, especially in the developing countries;

(b) to provide an international forum for scientific contacts between scientists from all countries; and

(c) to provide facilities to conduct original research to its visitors, associates and fellows, principally from developing countries.

2. Range of scientific disciplines

The programmes of the ICTP encompass a large spectrum of scientific disciplines from the most sophisticated subjects like the ultimate structure of elementary particles, down to more practical domains like remote sensing or telematics. Table I shows the range of the scientific disciplines which are or have been dealt with by the ICTP.

TABLE I

ICTP Fields of Research and Training-for-Research

Fundamental Physics	High Energy and Particle Physics Relativistic, Cosmology and Astrophysics
Physics of Condensed Matter	Condensed Matter Physics and related Atomic, Molecular Materials Science Surfaces and interfaces Liquids and statistical mechanics
Mathematics	Applicable Mathematics System Analysis, Mathematics of Development, Mathematics in Industry Algebra Geometry Topology Differential equations Analysis Mathematical Physics
Physics and Energy	Nuclear Physics and Fission Plasma Physics and Nuclear Fusion Non-conventional Energy (Solar, Wind and other)
Physics and Environment	Geophysics Soil Physics Seismology Climatology and Meteorology Physics of the Oceans Physics of Desertification

	Physics of Desertification Physics of the Atmosphere, Troposphere, Magnetosphere and Aeronomy
Physics Teaching	
Physics of the Living State	Neurophysics Biophysics Medical Physics
Applied Physics	Physics in Industry Microprocessors Communications Instrumentation Synchrotron Radiation Lasers Computational Physics Space Physics

3. Activities

The activities of the ICTP include several components, i.e. (a) research, (b) high-level training courses, (c) training in Italian laboratories, (d) external activities, (e) book and scientific equipment donation programme, and (f) training laboratories.

3.1 Research is carried out throughout the year in fundamental physics, physics of condensed matter and mathematics. A small permanent international staff, full professors of the Department of Theoretical Physics of the University of Trieste and of the International School for Advanced Studies (ISAS) and senior visiting scientists provide guidance to younger and less experienced physicists and mathematicians invited for periods ranging from one to twelve months and coming from all over the world. The ICTP also welcomes postdoctoral fellows for one or two years.

3.2 High-level training courses and workshops, conferences and topical meetings - Soon after the creation of the ICTP, it was realized that the scientific cadres of developing countries needed additional training for updating their research if they were to be competitive on the international scene. With this purpose in mind, high-level courses were instituted in condensed matter physics, nuclear physics, plasma physics and in mathematics during the first five years of existence of the ICTP. Many other subjects were added later (see Table I). High-level training courses have a duration of three to ten weeks and are attended by 70-90 participants mostly from developing countries.

Workshops, as a rule, differ from the courses in that they are more research-oriented and lectures are less numerous, leaving more time for discussion and research. In principle, they cater for already experienced scientists. In addition to them, the ICTP organizes conferences and topical meetings on advanced subjects.

Between thirty-five and forty courses, workshops, conference and other meetings are now held each year. As an illustration, Table II shows the programme for 1989.

Table II
1989 Programme

Fourth International Workshop on Computational Condensed Matter Physics: "Total Energy and Force Methods", 4 - 6 January.
Workshop on Theoretical Fluid Mechanics and Applications, 9 - 27 January.
Course on Basic Telecommunications Science, 9 January - 3 February.
College on Atomic and Molecular Physics: Photon Assisted Collisions in Atoms and Molecules. 30 January - 24 February.
College on Theoretical and Experimental Radiopropagation Physics, 6 - 24 February.
Workshop on Space Physics: Materials in Microgravity, 27 February - 17 March.
Workshop on Remote Sensing Techniques with Applications to Agriculture, Water and Weather Resources, 27 February - 21 March.
Experimental Workshop on High Temperature Superconductors, 30 March - 14 April.
Spring School and Workshop on Superstrings, 3 - 14 April.
Workshop on Radon Monitoring on Radioprotection, Environmental Radioactivity and Earth Sciences, 3 - 14 April.
Topical Meeting on Hyperbolic Geometry and Ergodic Theory, 17 - 28 April.
Spring College on Materials Science on "Ceramics and Composite Materials", 17 April - 26 May.
Conference on Oxygen Disorder Effects in High T_c Superconductors, 18 - 21 April.
Fourth Workshop on Perspectives in Nuclear Physics at Intermediate Energies, 8 - 12 May.
Spring School on Plasma Physics, 15 May - 9 June.
Working Party on Modelling Thermomechanical Behaviour of Materials, 29 May - 16 June.
Working Party on Fracture Physics, 29 May - 16 June.
Second ICFA School on Instrumentation in Elementary Particle Physics, 12 - 23 June.
Miniworkshop on "Strongly Correlated Electron Systems", 19 June - 21 July.
Research Workshop in Condensed Matter, Atomic and Molecular Physics, 19 June - 29 September.
Interface between Quantum Field Theory and Condensed Matter Physics (Anniversary Adriatico Research Conference), 20 - 23 June.
Summer School in High Energy Physics and Cosmology, 26 June - 18 August.
Quasicrystals (Anniversary Adriatico Research Conference), 4 - 7 July.
Workshop on Superstrings, 12 - 14 July.
Conference on Supermembranes and Physics in 2+1 Dimensions, 17 - 21 July.
Strongly Correlated Electron Systems (Anniversary Adriatico Research Conference), 18 - 21 July.
Symposium on "Highlights in Condensed Matter Physics", 1 - 3 August.
Workshop on Phenomenology in High Energy Physics and Cosmology, 16 - 18 August.
Topical Meeting on Variational Problems in Analysis, 28 August - 8 September.
Computations in Physics and and Physics in Computation (Anniversary Adriatico Research Conference), 5 - 8 September.
Adriatico Working Party on Condensed Matter Properties of Neutron Stars, 11 - 29 September.
Workshop on Materials Science and Physics of Nonconventional Energy Sources, 11 - 29 September.
Conference on Lasers in Chemistry, 18 - 22 September.
Workshop on Interaction between Physics and Architecture in Environment Conscious Design, 25 - 29 September.
Trieste Conference on Recent Developments in Conformal Field Theories, 2 - 4 October.
Fifth College on Microprocessors: Technology and Applications in Physics, 2 - 27 October.
Workshop on Soil Physics, 9 - 27 October.
College on Differential Geometry, 30 October - 1 December.
25th Anniversary Conference on "Frontiers in Physics, High Technology and Mathematics", 31 October - 3 November.
Workshop on Telematics, 6 - 24 November.
ICTP & INFN Course on Basic VLSI Design Techniques, 6 November - 1 December.
Third Autumn Workshop on "Atmospheric Radiation and Cloud Physics", 27 November -15 December.

3.3 The programme for training and research in Italian laboratories is the third component of the ICTP activities. It enables experimentalists from developing countries to participate in the research activities of laboratories belonging to universities or governmental and industrial institutions. Grants are given for periods ranging from a few months to one year, depending on the conditions set by the host laboratory.

The programme was established in 1983, thanks to a grant from the Direzione Generale per la Cooperazione allo Sviluppo of the Italian Ministry of Foreign Affairs and to the responsiveness of the Italian academic world, the Consiglio Nazionale delle Ricerche (CNR), the Istituto Nazionale di Fisica Nucleare (INFN) and the Comitato Nazionale per la Ricerca e per lo Sviluppo dell'Energia Nucleare e delle Energie Alternative (ENEA) which provide grants for up to a total of 80/90 man/months per year.

The network of host institutions include now more than two hundred laboratories.

3.4 The fourth component is the **External Activities Programme**. The rationale for this programme is that though the ICTP has been successful in training for research several thousands of scientists in Trieste, little had been done for building up communities of scientists in their own milieu. It is true in the early seventies the ICTP had provided a modest financial assistance to meetings, schools or conferences organized in the more advanced developing countries. A more important effort had however to be done if the investment was to have a lasting impact. Again, a grant from the Direzione Generale per la Cooperazione allo Sviluppo allowed the ICTP to tackle the problem in a bigger way. An Office for External Activities was created in 1985 and became operational in 1986. In a first phase, the ICTP provided financial as well as intellectual assistance in five programmes, i.e. *training activities, workshops, conferences, physics and mathematics teaching, visiting scholars* who help research groups wishing to embark on a new major project or introduce a new line of research. It sponsored 104 activities in 40 countries in 1988.

In a second phase, the ICTP will give special attention to the formation of scientific networks and the establishment of centres.

3.5 Another important component of the ICTP is its **Book and Scientific Equipment Donation Programme**. The book donation programme was initiated at the ICTP some years ago to provide universities in developing countries with books, journals and proceedings. These publications are normally donated to the ICTP by individuals, libraries, publishing companies, international conferences and international organizations in industrialized countries for distribution among libraries in developing countries.

The ICTP receives unused surplus scientific equipment from laboratories such as CERN which are then shipped to institutions in developing countries once selected by a scientist from the recipient laboratory.

3.6 The **Microprocessor Laboratory** is the sixth component of the ICTP activities. It was created in 1985. It is jointly operated with the Istituto Nazionale di Fisica Nucleare of Italy and it is sponsored by the United Nations University (Tokyo, Japan). The laboratory helps scientists from developing countries to get acquainted with microprocessor technology and to develop projects of their own which they will use in their home countries. Seven such projects were carried out in 1988. It also provides technical support to other activities taking place at the ICTP or outside.

3.7 To end with, the **High-Temperature Superconductivity Laboratory** initially established for teaching purposes in 1987, has acquired new equipment which will turn it into a research laboratory. Five scientists joined the laboratory in February March 1989 and will carry out research in structural and microstructural related properties in high-T_c superconductors, composites of Bi, growth of crystals and their characterization, and superconducting systems.

4. Networks - Associate and Federation Scheme

4.1 One of the reasons for which the Centre was created, was to check the *brain-drain* which made the best scientists from the developing countries to emigrate to the advanced nations where they would find a congenial atmosphere for the progress of their research. Something had to be done to break the isolation of the scientists who had chosen to remain in their countries - an isolation due to the lack of opportunities to discuss with their colleagues or to attend international conferences and the nearly total absence of scientific journals and books in their libraries. The response of the ICTP to this necessity was the creation in 1964 of the

Associate Membership Scheme. Associate Members are scientists from and working in developing countries who are appointed for a period of six years during which they are entitled to three research visits to the ICTP. Each of such visits should not exceed three months but should last more than six weeks. During their stay at the ICTP, Associate Members work either independently or in collaboration with other scientists in residence.

In 1989, the list of appointed Associate Members includes 415 scientists from 64 nations.

Some of the former Associates who have acquired international reputation or have distinguished themselves as *entrepreneurs* in their home countries in research or education, may be appointed as **Senior Associates** for six years. A fund of 4,000 US$ is reserved for each of them from where they may draw for their travel and subsistence at the ICTP. In 1989, the ICTP list of Senior Associates includes 58 names from 21 Member States.

For younger scientists, the ICTP has set up the **Junior Associateship**, a scheme which is mainly meant to help those working in institutions in developing countries with poor library facilities. Junior Associates are selected among participants in courses or workshops and during their four-year appointment they are entitled to order books through the ICTP or subscribe to scientific journals for their home libraries up to 350 US$ each year. In 1989, the ICTP counted 151 Junior Associates mostly from Asia and Africa.

4.2 In 1964 also, the ICTP devised a scheme for relatively nearby universities from Austria, Yugoslavia and Hungary to have regular access to its activities. This was the **Federation Scheme.** Again, this scheme proved to be the genuine response to a widespread need. Federated institution are entitled to send junior scientists to the ICTP for a total number of days which may vary from 40 to 120, depending on the geographical location of the institution. The subsistence expenses of the visitor are borne by the ICTP, while, as a rule, the federated institution bears the cost of travel. The ICTP may however contribute partially to the travel costs. There have been also special arrangements with the Kuwait Foundation for Science, Kuwait University (for nationals from Arabic and Islamic countries), the Islamic Republic of Iran, the University of Qatar, the Government of Argentina, the Brazilian National Research Council (CNPq) and the Arab Bureau of Education in Saudi Arabia which contribute fixed sums each year in support of their nationals. Three hundred and eighty-three institutions are federated with the ICTP this year (see Table III).

Table III
Federation agreements in 1989

Geographical area	Number of Agreements	Countries
Africa	107	Algeria, Benin, Burundi, Cameroon, Côte d'Ivoire, Egypt, Ethiopia, Gabon, Ghana, Guinea, Kenya, Liberia, Libya, Madagascar, Mali, Mauritania, Morocco, Niger, Nigeria, Senegal, Sierra Leone, Somalia, Sudan, Swaziland, Tanzania, Tunisia, Zambia
Asia	159	Bangladesh, P.R. China, India, Iran, Iraq, Israel, Jordan, Korea Rep., Kuwait, Lebanon, Malaysia, Nepal, Pakistan, Philippines, Qatar, Saudi Arabia, Sri Lanka, Syria, Thailand, Vietnam, Israel-West Bank, Yemen A.R., Yemen P.D.R.
Europe	69	Austria, Bulgaria, Czechoslovakia, German Dem.Rep., Greece, Hungary, Poland, Portugal, Romania, Spain, Turkey, USSR, Yugoslavia
North & Central America	23	Cuba, Dominican Republic, Honduras, Jamaica, Mexico, Puerto Rico, Trinidad
South America	24	Argentina, Brazil, Chile, Colombia, Ecuador, Guyana, Peru, Venezuela
Indonesia and Oceania	1	Indonesia

In 1988, 514 scientists came to Trieste under the Federation Scheme for a total of 470 man/months.

Tables IV and V show summary statistics on the 1988 programme and the period 1970-1988 respectively.

5. Facilities

The activities of the ICTP take place in four different buildings. The first one, the Main Building, has one lecture hall, 80 desks for scientists and a reading room and houses the bulk of the library collections, the computing facilities (40 personal computers, 15 IBM PS/2, 10 Olivetti M28, 10 Olivetti M380, some Olivetti M24 – most of which in the Adriatico Guest House – 12 SUN 386-1 workstations, a Convex C210 supercomputer and a MicroVAX) and a cafeteria. A second building, equal in size to the Main one and adjoining it, is being built and will have three additional small lecture halls. Its construction will be completed in early 1990. Two other buildings, the Galileo and the Adriatico guest houses, can accommodate 80 and 145 scientists, respectively, in double rooms. For the time being, those having a room in the guest houses use them as offices. In the Galileo there is also a lecture hall whereas in the Adriatico there are two large lecture rooms, studies for physicists, several smaller discussion rooms, a meeting room, a room for informatics, several PC's and computer terminals, the high-temperature superconductivity laboratory, a reading room, a Library which contains mostly condensed matter journals and a cafeteria. All Adriatico Research Conferences and the Summer Workshop in Condensed Matter Physics are held at the Adriatico Guest House. All administrative and financial services to scientists (Finance, Travel, Housing and Visas) have their offices at the Adriatico Guest House; others (Training in Italian Laboratories, Associates and Federation Scheme) are at the Galileo Guest House. A fourth building houses the Laboratory of Microprocessors.

6. Fraternal Relations

The ICTP has fraternal relations with centres for developing countries, both in the industrialised countries as well as in the developing countries. Some of these may be mentioned here, like the United Nations University, the New Centres for Genetic Engineering and Biotechnology in Trieste and in Delhi and the International Development Research Centre in Canada which spends of the order of Canadian $150 million a year on helping developing country research.

7. Funds

The ICTP draws its financial resources from the International Atomic Energy Agency (IAEA), the United Nations Educational, Scientific and Cultural Organization (UNESCO) and, mainly, from the Government of Italy for its regular activities. The Italian General Directorate for Cooperation to Development provides funding for special projects. In particular, it bears nearly all the costs of the programmes for training in Italian Laboratories and of the External Activities. The Swedish Agency for Research Cooperation with Developing Countries (SAREC) supports part of the Associateship Programme. Other contributions are received from the Arab Fund, Brazil, the Government of Japan, the Kuwait Foundation for the Advancement of Sciences, Qatar, the Royal Society (UK), the United Nations University and the National Academy of Sciences and Arts (USA). The annual budget of the ICTP is of the order of US$ 16.6 million.

Table IV
Statistical summary on activities held at and outside the ICTP in 1988

Activity	**Number of Visitors** Dev.	Ind.	Total	**Number of Man/months** Dev.	Ind.	Total
1. At the ICTP:						
(a) Research	379	150	529	802.09	178.79	980.88
(b) Training for research (courses, workshops and conferences)	2102	1890	3992	1833.62	688.39	2522.01
2. Outside activities:						
Italian laboratories	170	-	170	1093.76	-	1093.76
GRAND TOTAL*	2551	2040	4691	3729.47	867.18	4596.65

Figures on research include long- and short-term scientists as well as Associate Members, some scientists from Federated Institutes and seminar lecturers.

* Actual number of visits (some scientists took part in more than one activity). The actual number of scientists is

1988	2220	1894	4114	3729.47	867.18	4596.65

TABLE V

Overview of ICTP activities: scientists and scientific preprints since 1970

Year	No. of Scientists		No. of Man/months		No. of preprints		No. of Member States represented	
	Total	from Dev. countries	Total	from Dev. countries	Total	from Dev. countries	Total	Dev. countries
1970	582	218	864	389	154	81	53	35
1971	885	338	533	323	160	125	68	37
1972	888	407	1214	697	161	108	71	53
1973	878	352	1258	738	194	142	64	47
1974	862	329	854	588	141	104	65	48
1975	928	399	1018	664	172	141	82	62
1976	962	387	820	563	127	102	71	54
1977	1331	644	1080	776	158	108	92	71
1978	1327	655	1079	791	160	116	91	70
1979	1470	619	961	608	167	108	90	68
1980	1461	615	1296	991	183	148	93	72
1981	1933	960	1533	1148	239	159	90	70
1982	2139	978	1749	1278	236	179	83	63
1983	2188	1160	1810	1397	238	186	99	79
1984	2082	1086	1870	1425	249	210	96	76
1985	2720	1671	2669	2179	313	266	109	89
1986	3651	2180	3820	3149	401	323	109	86
1987	3700	2171	3899	3247	421	358	120	91
1988	4114	2220	4597	3729	428	368	120	94

APPENDIX II

THE THIRD WORLD ACADEMY OF SCIENCES

by Mohamed H.A. Hassan
Executive Secretary

I. Foundation of the Third World Academy of Sciences

The idea of setting up a Third World Academy of Sciences was conceived by Professor Abdus Salam of Pakistan on the occasion of a general meeting of the Pontifical Academy of Sciences of the Vatican in Rome on 6 October, 1981. After discussing the idea with Members of the Pontifical Academy from the Third World, a Memorandum was drawn up in support of the initiative, with the aim of exploring the possibility of creating such an organization. The signatories of this declaration were: C. Chagas (Brazil), H. Croxatto (Chile), J. Döbereiner (Brazil), M.G.K. Menon (India), T.R. Odhiambo (Kenya), C. Pavan (Brazil), M. Roche (Venezuela), Abdus Salam (Pakistan) and S. Siddiqui (Pakistan).

The signatories of the 1981 declaration decided to invite eminent men and women of science from developing countries, who had already attained recognition through their election into internationally recognized science academies, to become Founding Fellows. Twenty-eight Third World scientists, members of nine of the world's prestigious academies, were identified, and they agreed to become Founding Fellows of the proposed Academy. The Founding Fellows decided to invite distinguished scientists satisfying the same criteria, who were either ex-nationals of developing countries or had distinguished themselves in the context of Third World science, to become Associate Founding Fellows. Professor Abdus Salam was asked to coordinate the invitation and to prepare for the first meeting of the Academy.

The Foundation Meeting of the Academy took place in Duino Castle and at the University of Trieste, Italy, during the period 10-11 November, 1983, under the sponsorship of the Trieste International Foundation.

On 5 July, 1985, the Third World Academy of Sciences (TWAS) was officially launched by the United Nations Secretary Mr. J. Perez de Cuellar, in Trieste, Italy, on the occasion of the opening of a Conference on "South-South and South-North Cooperation in Sciences", which was organized by the Academy. The Conference, which marked the Academy's real birth, was attended by 250 delegates, representing Academies and Research Councils from the South and the North, and representatives of International Organizations.

The Academy is the first international forum to unite distinguished men and women of science from the Third World, with the objective of promoting basic and applied sciences in the Third World through nurturing excellence and fostering future generations of promising scientists from developing countries.

The Academy is a non-governmental, non-political and non-profit making organization, whose objectives are to recognize and promote high calibre scientific research carried out by scientists from developing countries, to facilitate their mutual contacts, strengthen their scientific research work and foster it for the development of the Third World and in the service of mankind.

The Academy became a Scientific Associate of the International Council of Scientific Unions (ICSU) in 1984 and was granted official NGO status by the United Nations Economic and Social Council in 1985. It is presently located on the premises of the International Centre for Theoretical Physics at Miramare, Trieste, Italy, a Centre sponsored by the International Atomic Energy Agency (IAEA) and the United Nations Educational, Scientific and Cultural Organization (UNESCO).

II. The Membership

The Membership of the Academy consists of Fellows, Associate Fellows and Corresponding Fellows. Fellows are elected from among scientists of developing countries who have made outstanding contributions to their respective field of science. Associate Fellows are elected from among citizens of industrialized countries who either have their origin in developing countries or have distinguished themselves in the context of Third World science, and who have attained highest international standards. Corresponding Fellows are elected from among promising scientists of developing countries.

At present, there are 131 Fellows, coming from 42 developing countries, 49 Associate Fellows and 19 Corresponding Fellows. Out of these 199 Members, 83 are also members of nine of the world's prestigious Academies and 10 are Nobel Laureates of Third World origin.

III. Objectives

The principal objectives of the Academy are:

(a) To recognize and support excellence in scientific research performed by individual scientists from the Third World;

(b) To provide promising scientists in the developing countries of the South with the conditions necessary for the advancement of their work;

(c) To promote contacts between research workers in developing countries of the South among themselves and with the world scientific community;

(d) To provide information on and support for scientific awareness and understanding in the Third World;

(e) To encourage scientific research on major Third World problems.

IV. Current Programmes

The Academy has designed a number of programmes to fulfil its overall objectives. In initiating and developing these activities, care has been taken not to duplicate the work of other organizations with common aims. Accordingly, special consideration is given to those programmes which the Academy is uniquely fitted to promote and which are likely to provide substantial enhancement to high-level scientific research in the Third World. A brief description of these programmes is given below.

1. Recognizing and Supporting Scientific Excellence and Encouraging the Pursuit of Science in the Third World

TWAS Awards

The Academy awards prizes to individual scientists from developing countries who, in the opinion of the Council, have made outstanding contributions to the advancement of science. Consideration is given to proven achievements judged particularly by their national and international impact. Candidates for the Awards must be nationals of developing countries, as a rule working and living in those countries. Nominations for each Award are considered by a committee of distinguished scientists appointed by the Council. The Awards are usually presented on a special occasion, normally coinciding with the General Meeting of the Academy and/or a General Conference organized by the Academy. Recipients of the Awards are expected to give lectures about the work for which the Awards have been made. Five Awards in Basic Sciences (Biology, Chemistry, Mathematics, Basic Medical Sciences and Physics) are conferred annually, effective from 1985. Each Award consists of a prize of US$10,000 as well as a medal.

Prizes to Young Scientists in Developing Countries

The Academy offers financial assistance to Academies and Research Councils in some twenty Third World countries to enable them to institute Prizes and Medals for young scientists in their countries. The Prizes, which normally amount to US$2,000 each, are usually awarded annually and rotate among the four fields of Pure Science: Biology, Chemistry, Mathematics and Physics.

2. Supporting Research Projects and Scientific Infrastructure in the Third World

TWAS Research Grants

The Academy provides direct research grants to promising scientific research work and research projects carried out in developing countries. Applicants must be nationals of Third World countries, living and working in the Third World. The grants are intended to cover the cost of purchasing scientific equipment, expendable supplies, scientific literature, field studies and services not normally available within the Institute where the research is to be carried out. The Programme currently covers the fields of Experimental Physics, Mathematics, Biochemistry and Molecular Biology. Grants for projects in these fields are normally for one year and amount to a maximum of US$5,000.

Provision of Spare Parts for Scientific Equipment in Third World countries

The Academy provides funds for covering the cost of small items of spare parts for scientific equipment which cannot be obtained or manufactured locally. In general, the support is provided for spare parts costing not more than US$500 each.

Provision of Books and Journals to Third World Libraries

In collaboration with the International Centre for Theoretical Physics (ICTP), the Academy provides scientific publications to a number of libraries in developing countries facing severe shortage in foreign currency, which hinders the purchase of important scientific textbooks and international interdisciplinary journals.

The Academy and the ICTP have recently made a joint appeal to libraries, publishing companies, laboratories and individuals to donate books, journals, proceedings and equipment to developing countries. The cost of packing and transportation of suitable material is covered by the Academy and ICTP. The response to this appeal has been very encouraging, and several international organizations and publishing companies (including the ICSU Press) have agreed to offer help in this programme.

The Academy also purchases copies of popular scientific publications of general interest, produced in the Third World, for distribution to local libraries and/or libraries within the same region.

3. Promoting South-South and South-North Collaboration

South-South Fellowships

The aim of the Fellowship Programme is to facilitate and promote mutual contacts between research scientists in the Third World and to further relations between their scientific institutions. Fellowships covering travel costs are awarded for visits to scientific institutions within the Third World for a minimum period of four weeks. Living expenses are borne by local sources. The Fellowships are offered to nationals of developing countries, normally with research experience and with positions in universities or research institutions in those countries.

Governments and scientific organizations in Argentina, Brazil, Chile, China, Colombia, Ghana, India, Iran, Kenya, Madagascar, Mexico, Vietnam and Zaire have so far agreed to provide local hospitality for a total of over 250 annual visits under this programme.

TWAS/ICTP Fellowships

This joint programme supports South-South exchange visits for scientists from institutions in the Third World federated to the International Centre for Theoretical Physics (ICTP), Trieste. An Institute may send one visitor per year to another Federated Institute in the same region. A Fellowship covers travel costs and per diem for a maximum of 30 days. Travel costs are covered by the Academy, while ICTP covers the per diem.

TWAS/ICIPE Associateship Scheme

The Academy and the International Centre of Insect Physiology and Ecology (ICIPE) in Nairobi, Kenya, have instituted a joint associateship programme for visits to ICIPE.

Associates are selected from among senior researchers in various aspects of insect science, who are nationals of developing countries and are working and living in those countries. They are appointed for a fixed period of six years during which they are entitled to visit ICIPE three times, each for a minimum period of three weeks and a maximum of three months. The Academy covers travel expenses, while ICIPE provides local support. A number of 7 Associates have so far been appointed.

The Academy plans to institute a similar programme with other centres of excellence in the Third World.

Support for Scientific Meetings

The Academy encourages the organization of scientific meetings in biological, chemical and geological sciences in Third World countries by providing financial support in the form of travel grants for principal speakers from abroad and/or participants from the region. Special consideration is given to those meetings which are likely to benefit the scientific community in the Third World and to promote regional and international cooperation in developing science and its applications to the problems of the Third World.

Fellowships for Research and Training in Italian Laboratories

The Academy supports visits by Third World scientists to laboratories in Italy active in the fields of biological, chemical and geological science, for the purpose of pursuing research or training. The Fellowship covers living expenses in Italy for a period of six months to one year. Limited funds for travel expenses to Italy are also available in the case these are not covered by other sources. About one hundred Italian Laboratories have already agreed to receive scientists from developing countries. The programme is expected to promote the establishment of institutional links and long-term cooperation between scientists in Italy and in the Third World.

ICSU/TWAS Programme of Lecturers

The International Council of Scientific Unions (ICSU) and the Academy have recently launched a joint Lectureship Programme. The general objective of this programme is to provide scientists in developing countries with the opportunity for discussions and scientific collaboration with colleagues from other countries who have made outstanding contributions to the advancement of science. ICSU and the Academy have compiled a Roster of Lecturers, comprising the names of scientists who have expressed an interest and willingness to participate in this programme. Under this joint programme, ICSU and the Academy will finance the travel of the lecturers to the country or countries which have invited them. Host country institutions will be expected to cover local expenses for the lecturers as well as to make all local arrangements.

Action on Drought, Desertification and Food Deficit (DDFD) in Africa

The Project is a joint venture initiated by the Academy, the African Academy of Sciences (AAS) and the National Academy of Sciences of the USA. It is supported by the Academy, the World Bank and the MacArthur Foundation. The aim of the project is to deploy Science and Technology in overcoming Drought, Desertification and Food Deficit in Africa. A Task Force of internationally renowned scientists was set up in July 1985, and its first meeting was held in Trieste in December 1985. The DDFD Project was officially launched at an international conference in Nairobi in June 1986. An international fact finding mission on biotechnology and long-term soil and water management was organized by the three academies, which visited a number of African countries during 1987.

TWAS General Conferences

Every two years the Academy organizes a general conference on South-South and South-North cooperation in sciences, in conjunction with the general meeting of the Academy. Presidents of Academies and Research Councils in developing and developed countries, as well as representatives of international organizations and foundations, are normally invited to attend the conference.

The Academy will convene its Third General Conference in Colombia, during the period of *16-20 October 1989*. The Conference, which will be hosted by the Colombian Academy of Exact, Physical and Natural Sciences, will focus on discussing the future of science in Latin America and the Caribbean, with special reference to the role of science in national planning and the prospects of South-South and South-North collaboration. Specialized scientific symposia on vaccines and natural hazards will also be organized during the Conference.

4. TWAS Publications

The Academy publishes a quarterly Newsletter covering news about scientific and technological activities in the Third World, news about the Academy and recent scientific discoveries. Other publications of the Academy include the Year Book, Proceedings of TWAS General Conferences and Proceedings of Roundtables and specialized meetings.

The Academy has received funds from the Kuwait Foundation for the Advancement of Sciences in support of the publication of a Third World Journal of Science and Technology. The Journal is being published in Nairobi, Kenya, jointly with the African Academy of Sciences (AAS), with the *Discovery and Innovation.*

V. Relations with Third World and International Scientific Organizations

In recognition of the importance of establishing close ties with leading scientific organizations in the Third World, the Academy has signed agreements of cooperation with over 60 Academies and Research Councils in 46 developing countries. The Academy has also signed a Memorandum of Understanding on Scientific Cooperation with the African Academy of Sciences (AAS), the Latin American Academy of Sciences (ACAL) and the Federation of Asian Scientific Academies and Societies (FASAS). Through this Memorandum, the Academy provides some financial assistance to each of the three regional Academies in support of their regional activities.

In the same spirit, the Academy has initiated the establishment of a Network of Scientific Organizations in the Third World. Over one hundred Academies, Research Councils and Ministries of Science, Technology and Higher Education have so far agreed to join the Network. In addition to strengthening cooperation between its members, the Network will further the contribution of the South to global science projects and areas of today's frontier science and technology which are most likely to have a strong impact upon the economic and social development of the Third World.

A number of cooperative activities between the Academy and the International Council of Scientific Unions (ICSU) are currently being pursued. These include a joint ICSU/TWAS Lectureship Programme in developing countries, the establishment of a computerized data bank on major scientific institutions active in the Third World, the provision of books and journals to libraries and institutions in developing countries and the encouragement of the least developed countries to join ICSU and the Scientific Unions as a group.

VI. Finance

The financial resources of the Academy for the 1988 programmes and projects are, at present, derived from the Italian Government (through the *Direzione Generale per la Cooperazione allo Sviluppo*), the Canadian International Development Agency (CIDA), the Kuwait Foundation for the Advancement of Sciences (KFAS), the OPEC Fund for International Development, the *Consiglio Nazionale delle Ricerche (CNR)*, and the Government of Sri Lanka.

Governments and scientific organizations in 13 developing countries have agreed to provide financial support to cover local expenses for more than 250 visits to their countries under the South-South Fellowship programme of the Academy.

Statistical Summary of Activities in and for Third World Countries supported by TWAS (1986 — 1988)

Country	Scientific Meetings	Research Grants	South-South Fellowships	Italian Labs Visits	Libraries Receiving Journals	Institutions Receiving Books	Spare Parts	TWAS Awards	Prizes for Young Scientists	Lectures Held
Afghanistan						2				
Algeria		1					1			
Angola		1				1				
Argentina	16	30	5	3		5	9			
Bangladesh	3	6	5	1	14	21	1		2	1
Barbados		1								
Benin		1	1		4	5				1
Bolivia	1	1	1	2	8	4	2		2	
Botswana		1				2				
Brazil	9	9	5	3		7	1	3		1
Burkina Faso						3				
Burma		1			8	4				
Burundi				3	8	5				
Cameroon		1			4	4				
Chad						1				
Chile	15	31	5		8	20	20			
China	17	60	9	10	2	10	41	3		4
Colombia	2	2	3		6	14	2		2	
Congo		2	1		2	1				
Costa Rica	1	2			2	4				
Côte d'Ivoire		2			4	2	1			
Cuba	3	6	1	2	8	12	1			
Dominican Rep.						1				
Ecuador	1				4	2	1			1
Egypt	2	4	2	2	6	11	3	1	2	1
El Salvador					2	5				
Ethiopia	1	2	1	4	8	9	3			
Fiji	1					1	2			
Gabon	1					2				
Ghana	3	2	1		8	13	2			
Guatemala						2				
Guinea	1		2		2	3				
Haiti						1				
Honduras	1					2				
India	18	23	5	8		4	3	3	3	2
Indonesia	1			2		5	1			
Iran		4	1							

Statistical Summary of Activities in and for Third World Countries supported by TWAS (1986 — 1988)

Country	Scientific Meetings	Research Grants	South-South Fellowships	Italian Labs Visits	Libraries Receiving Journals	Institutions Receiving Books	Spare Parts	TWAS Awards	Prizes for Young Scientists	Lectures Held
Iraq	1	1				1	2			
Jamaica	1	3							1	
Jordan	4	4		3	2	3				
Kenya	5	3	2		6	5	8		1	1
Korea, North			4							
Korea, South		2	1	1						
Lebanon		1			8	1				
Lesotho					6	2				
Liberia					2	7				
Madagascar	2	2			10	6				
Malawi					2	2				
Malaysia	5	4		1		3				
Mali					8	5				
Mauritania						1				
Mauritius			1			1				
Mexico	6	15	5	1		2	1	1	2	
Morocco	2	4		3	6	12				1
Mozambique						2				
Nepal		2	2	1	8	8			1	
Niger						4				
Nigeria	6	26	6	8	10	34	19			
Pakistan	6	21	2	8	12	26	12	1		1
Panama		1				3				
Papua N. Guinea	2					1				1
Paraguay					2	1				
Peru	1	3	2		8	9	1		1	
Philippines	1	5				2	1			2
Puerto Rico	1									
Rwanda		1				2				
Senegal	1			3	8	3				
Sierra Leone		3	1		6	7				
Singapore	1									1
Somalia		1			2	1				
Sri Lanka	2	10	5	1	8	21	18			
Sudan	2	5	5	2	12	16	1			
Suriname						1				
Swaziland					4	1				

Statistical Summary of Activities in and for Third World Countries supported by TWAS (1986 — 1988)

Country	Scientific Meetings	Research Grants	South-South Fellowships	Italian Labs Visits	Libraries Receiving Journals	Institutions Receiving Books	Spare Parts	TWAS Awards	Prizes for Young Scientists	Lectures Held
Syria	1	3		2	2	3	11			
Tanzania		1		1	8	15	4			1
Thailand	5	8	2	1		4	3			1
Togo						2				
Trinidad	2	2								
Tunisia	2				8	8				
Turkey	3	7		3	6	21	5			1
Uganda			1	2	8	6				
Uruguay	1	1	2		8	3	1			
Venezuela	2	8	3			1	1			1
Vietnam		6	1	3	2	1				1
West Bank		3			2	1				
Western Samoa						1				
Yemen, A.R.		1			8	3				
Yemen, D.P.R.					8	1				
Zaire		1		2	8	7				
Zambia					6	6	7			
Zimbabwe	1	2			8	8				
TOTALS	163	353	93	86	320	472	189	12	17	23

APPENDIX III

THE THIRD WORLD NETWORK OF SCIENTIFIC ORGANIZATIONS (TWNSO)

by Mohamed H.A. Hassan
Secretary General

I. FOUNDATION OF THE THIRD WORLD NETWORK OF SCIENTIFIC ORGANIZATIONS

During 1986, the Third World Academy of Sciences (TWAS) invited several national Science Academies and Research Councils in developing countries, with which TWAS had already established close links, to sign an agreement envisaging the strengthening of cooperative links between TWAS and these scientific bodies. An invitation was extended to some thirty Science Academies and Research Councils in the South, of whom twenty-three responded positively.

Encouraged by this positive response, the President of the Third World Academy of Sciences proposed at the opening of the TWAS Second General Conference in Beijing, China, in September 1987, that the TWAS initiative should be extended in scope and that a "Network" linking Science Academies, Research Councils and other leading scientific organizations in the South be formed with the full participation of Ministries of Science and Technology and Higher Education, in order to enhance communication and collaboration among them and to increase the effectiveness of science in the South. The South can then collectively have substantial input in frontier science programmes (such as biological studies of the human genome, space research and nuclear fusion), which may have particular significance to development in the Third World. The President's proposal was strongly supported by the representative of the Italian government attending the Conference, who in his opening address to the Conference pledged financial support for the "Network".

The "Network" proposal was subsequently discussed and endorsed by the participants of the Conference, among whom were Ministers of Science and Technology and Higher Education, Presidents of Science Academies and Chairpersons of Research Councils from more than 40 Third World countries. It was decided at the Meeting that an Ad-Hoc Committee under the chairmanship of Professor J. Aminu of Nigeria and the membership of Professors M.G.K. Menon of India and M. Roche of Venezuela, be set up to explore further the institution of the Network.

Academies, Research Councils and Ministries of Science, Technology and Higher Education in the South have subsequently been invited to join the Network as Members. It is hoped that this will make it possible for these bodies to apply the necessary political pressure, both within and outside the South, in support of the development of Science and Technology in the Third World. Scientific and technological organizations of expatriates of Third World origin living in industrialized countries have also been invited to become Associate Members of the Network. One-hundred-and-one scientific organizations from sixty-three Third World countries have agreed to become Members of the Network and six Expatriate Organizations have accepted to become Associate Members.

The Foundation Meeting of the Network was convened by the Third World Academy of Sciences at its Headquarters from 4 to 6 October 1988 and was attended by over ninety participants including 15 Ministers of Science and Technology and Higher Education, 12 Presidents of Academies and 17 Chairpersons of Scientific Research Councils from 36 Third World countries. The Meeting approved the Statutes for the Network and elected a President and an Executive Board for an interim period of one year. The Meeting also adopted a declaration referred to as "The Trieste Declaration on Science and Technology as an Instrument of Development in the South".

The office of the Network has been established within the Third World Academy of Sciences' Secretariat. In order to facilitate the operation of the Network, it has been decided to set up four regional offices at the location of the four Vice-Presidents, i.e. in Nigeria, Tunisia, Mexico and Malaysia.

At the second meeting of the Executive Board of the Network in March 1989 it was decided to set up three standing committees on: Natural and Man-made Hazards; Global Projects and Frontier Science; National and Regional Plans/Policy for Science and Technology; to advise the Board on these issues and to recommend plans of action.

The second meeting of the Network will be held in Bogota, Colombia, during the period 16-20 October 1989, in conjunction with the Third General Conference of the Third World Academy of Sciences.

The Network is a non-governmental, non-profit making and autonomous scientific organization. Its objectives and Membership structure are set out below.

II. OBJECTIVES OF THE NETWORK

The general objective of the Network is to promote South-South and South-North Cooperation in the development and application of Science and Technology in the Third World.

This may be achieved by:

(a) Furthering the contribution of the South to global projects of science *(such as Man and the Biosphere programme of UNESCO and the International Geosphere Biosphere Programme of ICSU);*

(b) Furthering the contribution of the South to areas of today's frontier science and technology which are most likely to have a strong impact upon the economic and social development of the Third World *(such as space science and technology, thermo-nuclear fusion, high technology and biotechnology);*

(c) South-South collaboration: Promoting and strengthening co-operation between Academies, Research Councils and scientific organizations in the Third World and enhancing their role in the development of the Third World, including information sharing through the setting-up of data banks.

(d) South-North collaboration: Furthering relations between scientific institutions and organisations in the South, and with their counterparts in the North through the development of bilateral links and exchange programmes.

(e) Encouraging Third World Governments to take appropriate political action to develop their scientific enterprise through self-reliance and adequate allocation of resources.

(f) Undertaking any other activities that will further the objectives of the Network.

III. MEMBERSHIP OF THE NETWORK

The *Membership* of the Network is open to the following organizations:

1. Ministries responsible for Science and Technology in the Third World;

2. Ministries responsible for Higher Education in the Third World;

3. National Science Academies in the Third World;

4. National Research Councils responsible for Science and Technology in the Third World;

5. Major Science and Technology foundations in the Third World;

6. Regional, inter-governmental and international organizations and centres promoting science and technology in the Third World;

7. Any other organizations promoting Science and Technology in the Third World which, in the judgement of the Council, are eligible for membership.

The *Associate Membership* of the Network is open to scientific and technological organizations of Third World origin of scientists working in industrialized countries, to Ministries and organizations corresponding to 1-6 above, provided that each case is treated on its own merit.

Membership will be given to qualified organizations that request it in writing and accept the Statutes of the Network.

Founding Member status will be given to organizations that have already requested membership and which have not withdrawn their request by 31 December 1988.

MEMBERS OF THE NETWORK:

1. National Academy of Exact, Physical and Natural Sciences
Avenida Alvear 1711, 4°
1014 Buenos Aires
Argentina

2. National Council of Scientific and Technical Research (CONICET)
Rivadavia 1917
1033 Buenos Aires
Argentina

3. Bahrain Centre for Studies and Research
c/o Ministry of Education
PO Box 43
Khalid bin Al-Walid Road
Qudhaibiya, Manama
Bahrain

4. Bangladesh Academy of Sciences
3/8 Asad Ave
Mohammadpur
Dhaka 7
Bangladesh

5. Bangladesh Council of Scientific and
Industrial Research
Mirpur Road
Dhanmondi
Dhaka 1205
Bangladesh

6. Ministry of Education, Science and
Technology and Culture
Bangladesh Secretariat
Bhabhan 7
2nd 9-Storey Building, 6th Floor
Dhaka
Bangladesh

7. National Council of Science and Technology
Ministry of Foreign Affairs
"Flodden"
Culloden Road
St. Michael
Barbados - West Indies

8. Ministry of Secondary and Higher Education
Cotonou
Benin

9. Bolivian National Academy of Sciences
Av. 16 de Julio No. 1732
P.O. Box 5829
La Paz
Bolivia

10. Brazilian Academy of Sciences
Rua Anfilófio de Carvalho 29
C.P. 229
20000 Rio de Janeiro, RJ
Brazil

11. National Council for Scientific and Technological Development
Av. W-3 Norte Quadra 507 Bl. B
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APPENDIX IV

Agriculture: Scientific Centres contributing to Third World Productivity

by Mario de Cautin

United by the support of the Consultancy Group on International Agricultural Research (CGIAR), but viewed with suspicion by transnational agroindustrial corporations, 13 centres for scientific research are making a difference to agricultural output in the Third World.

The Centres, located mostly in developing countries in different regions of the world, are creating seeds which are highly resistant to disease and frost, and which are yielding maximum productivity.

The results of experiments in cross-breeding that almost seem like witchcraft, the improved seeds help Third World governments, particularly in Africa and Asia, to deal with cyclical famines in their countries.

Perfection of strains of corn resistant to the weevil, wheat resistant to blight, potatoes capable of reproduction by seed instead of by the usual tuber, and rice which grows easily near salt-water shores, are among the projects scientists have undertaken in the 13 centres, said economist Rossina Salerno, Italian Government representative in the CGIAR, in an interview with IPS (Inter Press Service).

Salerno was recently in Mexico to visit the International Centre for the Improvement of Corn and Wheat (CIMMYT), founded in 1966, and one of the 13 centres.

On the staff of CIMMYT is Norman E. Borlaug, who oversees research on a highly resistant and highly productive strain of dwarf wheat, and whose work earned him the Nobel Peace Prize in 1970, in the absence of an award specifically designated for agricultural achievement.

Over the last two decades of its existence, CIMMYT experts have trained more than 2,500 scientists from various countries, and have created in its laboratories around 400 improved strains of wheat and corn.

Varieties of wheat obtained at the CIMMYT are now cultivated on 50 million hectares of land in 70 countries, while corn hybrids originating from Mexican breeds, including the famous 'tuxpeno' have been sown on three million hectares, according to Rossina Salerno.

The Italian economist told IPS that the complexity and the dimensions achieved by this kind of scientific centre, which freely hands over the results of their research to interested governments, has called attention to the need for official support.

Thus, the CGIAR was founded in 1971 with the aims of establishing other such centres, guiding their management, and guaranteeing them long-range economic backing.

Starting out with an annual budget of nine million dollars, the CGIAR - an organisation of simple structure and non-bureaucratic functioning - has aroused such an interest that it can presently dispose of 250 million dollars a year.

The contributions proceed from some twenty countries, from organisations like the United Nations Programme for Development (UNDP) and from private foundations.

The 'Group of 13' includes three centres devoted to research on tropical agriculture in Colombia, India and Nigeria, one in Syria concentrating on agriculture in arid zones, a fifth in the Philippines on cross-breeding of rice, and three on genetic improvement of cattle in Ethiopia, Kenya and the Ivory Coast.

The list includes the International Centre of the Potato in Peru, one in Rome, Italy, for the conservation of genetic resources in the so-called 'germoplasma banks', one in Holland for the fostering of rural agricultural cooperation, a twelfth in Washington in the United States for the study of nutrition, and, finally, the CIMMYT in Mexico City.

These centres focus on the cross-breeding and the creation of hybrids, and other scientific endeavours, but the job of multiplying the seeds and distributing them to farmers is a government responsibility, the Italian economist stressed.

The geographical location of the CGIAR centres is strategic rather than fortuitous: the Centre for Rice Studies, for example, is located in the Philippines, because Asia, which has 50% of the world's population, also consumes 90% of its rice and the Centre for Potato Research is in Peru, in the Andean Zone, where that root is said to have originated.

One of the successes achieved by the Peruvian Centre, Salerno explains, is that it is now possible to propagate potatoes with seeds, rather than with roots as has been the case up till now.

This system allows considerable financial savings, and makes a substantial quantity of the tuber available for human consumption.

Regarding the problems facing the centres, the Italian Government representative says the main one is the drastic limitations imposed by a modest budget.

The annual 250 million dollars are really not enough to achieve the aims of these 13 centres, whose ultimate goal is the feeding of 800 million undernourished people throughout the world.

Otherwise, she remarks, 'transnational agroindustrial corporations are very suspicious of these centres, because the CGIAR distributes improved seeds free to needy governments'.

The distrust is easily explained. There are in the world 46 of these transnational enterprises, of which 36 are based in the United States, which are at the head of a gigantic oligopolitical technological group and the international seed market, and which routinely abscond with Third World seed varieties and without respect for local patents.

In addition, according to the Latin American economic system (SELA), this handful of transnational corporations is also guilty of attempting to suppress native seed strains, reducing the world's nourishment to produce from 15 different seed types and limiting two thirds of world-wide grain cultivation to three crops: corn, wheat and rice.

(Taken from Special United Nations Service Bulletin (SUNS), No. 2135 of 12 April 1989).

APPENDIX V

Science, the Key to World Domination

by Kurt Mendelssohn

(Chapter One of Science and Western Domination published by Thames and Hudson, London, 1976.)

Five hundred years ago, when the ships of Prince Henry the Navigator edged their way along the coast of Africa in the first step towards dominating the world, Europe was desperately poor in comparison with the great civilizations of the East. Soon she was going to be made even poorer by wars and plagues. By then, however, the foundation of Europe's future wealth had been laid. Its roots lay in a single philosophical idea which today is called science, but whose old name, 'natural philosophy', provides a rather better description. ...

What is so spectacular is the rapid rise of science, and its fairly negligible effect on man's moral behaviour. Admittedly, science has offered an enhanced scope for the destruction of life, but it has done the same for its preservation and for the alleviation of suffering. In fact, for what it is worth, the world population has increased. ...

The object of this book is to trace the essential steps in thought that have led along the path of science to white domination over the rest of the world. It is neither a history of science nor an account of scientific achievement, but a history of those concepts and ideas of natural philosophy which have inexorably forced the West into a position of economic superiority. It was an enterprise in which greed came only second to the spirit of adventure. ... Natural philosophy in the modern sense could not be reborn because it had not existed before. Instead, it came into the world as something entirely new, a revolution that has shaped the lives of more people than any previous idea, the great religions included. Science has provided mankind with a new dimension which is both terrifying and exhilarating.

Before we can embark on our history of scientific ideas, something has to be said about the reason why natural philosophy has had this enormous impact on human affairs, which far exceeds the success of any other philosophical method. Its immense strength lies in its power of accurate prediction. ... An aero-engineer who, applying scientific principles, designs a new aircraft not only knows, even in the drawing-board stage, that his aircraft will be capable of flying, but he also can forecast, with a fair degree of accuracy, its performance. A political group, planning a new election campaign, does not necessarily meet with the same degree of success.

... The remarkable progress of science is thus merely a relative phenomenon, and it is a matter of taste whether we say that technological development has advanced or that human society has lagged behind. What is remarkable, on the other hand, is that the development of the scientific method should have been limited to European man. The amount of political and sociological trial and error in the great oriental civilizations is of the same order of magnitude as in Europe, and in all other respects, too, these civilizations compare well with the West.

The fact that Asia has now chosen to deviate from its traditional pattern and to follow the technological road demonstrates, better than any other argument, that the philosophical method of science is the most outstanding contribution which has been made to human progress in the last millennium. Since, for reasons unknown to us, scientific progress has not been matched by a corresponding development in morality, the white race has used this powerful method to dominate the globe. It seems that those who apologize for the latter fact tend to forget the achievement of having developed science in the first place. There is, moreover, no reason to believe that, if another civilization had developed science, it would have desisted from using if for exactly that purpose. ...

The primary object of scientific inquiry is to establish as many of these regularities as possible, and then to reduce their number by trying to find a common explanation for some of them. ...

There thus exists a secondary object of science, which introduces an element of control by testing the law to which the regularities have been reduced. This can be done either by making observations on a great number of similar regularities or, even better, by investigating corollaries of the law. In the case of general relativity, for example, it is a necessary corollary that a beam of light should deviate from its straight path when passing close by a massive object. Using the sun as the largest mass near at hand, and waiting for an eclipse to reduce its glare, we find that the apparent shift in the position of a star seen close to the sun can just be detected by our most accurate methods of observation. ...

We therefore have two grades of predictability in science. The more direct one deals with cases which have been investigated and used without doubt for safe prediction. If the circuit of an electric torch is closed by pressing the switch, a current will flow and the bulb will light up. This is accepted as quite certain even for a newly assembled, and as yet unused, torch. ...

The regularities concerning electric currents and their connection with magnetism were thoroughly investigated in the first half of the nineteenth century, and the laws of nature containing these regularities were formulated in 1865 by James Clerk Maxwell in a set of differential equations. These equations were able to account for all known observations and uses of electric currents but, as Maxwell noticed immediately, they allowed for other phenomena which had never been observed. From his equations Maxwell predicted the existence of electromagnetic vibrations, and such waves were eventually produced and detected a quarter of a century later by Heinrich Hertz. They form the basis of the whole technique of radio communication, including television. ....

It must be noted that in all these stages of using the scientific method of philosophy, observation plays a most important role.

In the first place, the experiment sees to it that speculation cannot run riot. When a set of observed regularities is combined into a theory, the next thing to do is to test this theory by experiment. ...

The other important function of the experiment is the discovery of new facts, such as the discovery of America which foiled Columbus's experiment to reach the Indies. Here we mean by 'new fact' not one of the suspected regularities, as with Maxwell and the radio waves, but some completely unsuspected phenomena. For instance, at the turn of the century there existed two rival theories according to which the electrical resistance of a metal should either drop gradually to zero, or rise gradually to an infinitely high value as the absolute zero of temperature is approached. A decision has to wait until a method for the close approach of absolute zero had been found. When in 1908 Kamerlingh Onnes in Leyden succeeded in doing this, he immediately performed the experiment and found that the first alternative was almost, if not quite, the correct one. In addition, however, had discovered that most metals will suddenly and completely lose their resistance a few degrees *above* absolute zero. This 'superconductivity' was an entirely new phenomenon which had no place in the earlier predictions. ...

The experiment requires instruments, and the instruments of science form a most important chapter in this branch of philosophy. The invention of new methods of exploration and measurement is an integral part of the peculiar intellectual adventure which gave the white man command of the earth. The conception and design of a new probe is a feat in science which in importance often parallels the concept of a new abstract idea. ...

The question has often been asked why the great civilizations of the East did not develop science and technology. The answer to this question was once given by Einstein, who pointed out that it is the wrong question. The miracle, he said, was not that the East failed to create experimental philosophy, but that the West did. However, why this happened is a riddle that has never been solved. To be candid, we simply don't know. It would indeed be rash to suggest that it was developed merely out of a desire to enslave others. But whether it was intended or not, this is what in the end happened. In addition to greed for riches and domination, the white man became possessed suddenly of a strange spirit of adventure, of an insatiable intellectual curiosity that has driven him on for the past five hundred years.

No ideas, not even scientific ones, grow in the test tube. They germinate and develop in men's minds, and these minds are conditioned by their environment. ... Science is that essential ingredient of Western civilization which distinguishes it from the cultures of others.

Original scientific ideas and concepts are basically the work of individuals rather than the collective effort of many, and the success of our world has for centuries now depended on the achievements of geniuses. That the execution of their ideas may often have to rely on the work of thousands of other people does not alter this fact. We thus have come to regard the leading role of the genius as a necessary and desirable feature of the world, and the names of men like Copernicus, Newton, Faraday and Einstein are deeply imprinted on the mind of the school-child. It is here perhaps, more than in any other respect, that the West differs from the civilizations of the East.

In China or India, regard for the achievement of the individual has been bestowed much more sparingly by society. It has been limited to the rare phenomenon of a great religious leader or a great philosopher. To Eastern peoples, harmony of mankind in general, both with the forces of nature and with other, has been the main aim of life; an attitude that fights shy of drastic innovation in an accepted pattern of existence. The belief that this pattern, which had been achieved in centuries of patient evolution and self-discipline long ago, must be maintained, contrasts profoundly with the West's obsession with change and progress. The men whose life and work form the subject of this book have never existed in the East because the East would have given them no encouragement.

Now, after rejecting consistently in the centuries past the blandishments of Western science, the Eastern nations have changed their minds and are absorbing, in a somewhat undigested form, the so-called blessings of Western science, from electronics to automatic weapons. Most of them are quite willing to build on this foundation without concerning themselves particularly with its origin. It rarely occurs to Easterners that the West too, might have a history, not only of wars but also of ideas. I know my colleagues in Delhi, Peking and Tokyo well enough to realize that after six p.m., or whenever their day's work is finished, they long to re-immerse themselves into the quiet solace of their own heritage. They simply have not time to bother about the West's. To them this book is dedicated.

APPENDIX VI

A State's Duties towards Science

I. In the context of a State's duties towards Science, permit me to present the proclamation 5461 of 17 April 1986 of the President of the United States of America. I wish similar proclamations could be made by the Presidents of the developing countries. This proclamation reads:

"Since the time of its beginnings in Egypt and Mesopotamia some 5,000 years ago, progress in mathematical understanding has been a key ingredient of progress in science, commerce, and the arts. We have made astounding strides since from the theorems of Pythagoras to the set theory of George Cantor. In the era of the computer, more than ever before, mathematical knowledge and reasoning are essential to our increasingly technological world.

"Despite the increasing importance of mathematics to the progress of our economy and society, enrollment in mathematics programmes has been declining at all levels of the American educational system. Yet the application of mathematics is indispensable in such diverse fields as medicine, computer sciences, space exploration, the skilled trades, business, defence, and government. To help encourage the study and utilisation of mathematics, it is appropriate that all Americans be reminded of the importance of this basic branch of science to our daily lives.

"The Congress, by Senate Joint Resolution 2261, has designated the week of April 14 through April 20 1986 as "National Mathematics Awareness Week" and authorised and requested the President to issue a proclamation in observance of this event.

"NOW, THEREFORE, I RONALD REAGAN, President of the United States of America, do hereby proclaim the week of April 14 through April 20 1986, as National Mathematics Awareness Week, and I urge all Americans to participate in appropriate ceremonies and activities that demonstrate the importance of mathematics and mathematical education to the United States.

"IN WITNESS WHEREOF, I have hereunto set my hand this seventeenth day of April, in the year of our Lord nineteen hundred and eighty-six, and of the independence of the United States of America the two hundred and tenth".

II. A similar and more recent proclamation has been made by President Reagan in respect of superconductivity. In view of its topicality, I repeat it here.

"THE PRESIDENT'S SUPERCONDUCTIVITY INITIATIVE.

"The President has announced an eleven-point initiative to promote further work in the field of superconductivity and ensure US readiness in commercialising technologies resulting from recent and anticipated scientific advances.

"The US has been a leader for years in the field of superconductivity - the phenomenon of conducting electricity without resistance. US private and Government researchers have also been at the forefront of recent laboratory discoveries allowing superconductivity to occur at higher temperatures and with greater current-carrying capacity than was previously possible.

"... The Federal Government is currently spending approximately $55 million on superconductivity research, with more than one half of that reallocated within the last six months.

"The President's initiative reflects his belief that it is critical that the US translate our leadership in science into leadership in commerce. While the US private sector must take the lead, the Administration is taking important actions to facilitate and speed the process, including increasing funding for basic research and removing impediments to procompetitive collaboration on generic research and production and to the swift transfer of technology and technical information from the Government to the private sector.

"... The Superconductivty Initiative includes both legislative and administrative proposals. ... The major components of the Initiative are:

1. "Establishing a "Wise Men" Advisory Group on Superconductivity under the auspices of the White House Science Council. ...
2. "Establishing a number of "Superconductivity Research Centres" ... that would: i) conduct important basic research in superconductivity; and ii) serve as repositories of information to be disseminated throughout the scientific community.
3. "... The National Science Foundation (NSF) will augment its support for research in high temperature superconductivity programmes at three of its materials research laboratories. In addition, NSF is initiating a series of "quick start" grants for research into processing superconducting materials into useful forms including wires, rods, tubes, films and ribbons.
4. "The Department of Defence is developing a multi-year plan to ensure use of superconductivity * technologies in military systems as soon as possible. The Department of Defence will spend nearly $150 million over three years. ..."

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* High temperature superconductivity is a subject to which fundamental contributions were made by Chinese physicists; Zhau Zhong Xian was awarded the annual $10,000 Physics Prize of the Third World Academy of Sciences on 14 September 1987). Apparently any nation may join in this potentially rich and, fortunately, still open quest if it can afford just thirty thousand dollars for equipment and for the physicists.

who make up the bulk of Britain's research potential. Concentration of university resources required by financial stringency has been going on for a long time and could be continued on a departmental basis without depriving entire universities of the right to do substantial independent research.

"The authors of the Report seem to believe that most good work is now done by large teams, but that is true of only some subjects. Monclonal antibodies were invented by two people. High temperature superconductivity was discovered by two men at IBM Zurich by research done on their own initiative. I understand that it was not part of the laboratory's "mission". W.F.H. Jarrett has developed a very promising vaccine against AIDS in the Veterinary School of the University of Glasgow; starting from small beginnings, it was done by a team of eight people in a department with about 30 graduates, not in a great interdisciplinary research centre. The entire Veterinary School is now under threat of closure by the UGC.

"My laboratory is often held up as a model of a centre of excellence, but this is not because I ever "managed" it. I tried to attract talented people by giving them independence, listening to them and taking an interest in their work, helping them to get what they needed for it and making sure that they got the credit for it afterwards. I also followed the tradition that I had learnt at the Cavendish Laboratory of letting young people publish their work independently, because I knew this to be one of the most important stimuli to originality. Had I tried to direct peoples' work, the mediocrities would have stayed and the talented ones would have left. The laboratory was never "mission-oriented". The National Institute for Medical Research was founded with the mission of developing antibiotics, but these have not been discovered there, while it has achieved great things in other fields. The FMBL Laboratory in Heidelberg is organised exactly as prescribed by the Report, but has achieved little commensurate with its enormous cost.

"The brilliance of British science is one of the country's greatest cultural achievements, if not the greatest, but it is a fragile flower as I know from Austria, my country of birth. Once destroyed by bad politics it cannot be restored."

APPENDIX VIII

Infinite in All Directions

by Freeman J. Dyson

(From "Manchester and Athens", Chapter 3 of Infinite in All Directions by Freeman Dyson (Harper and Row, New York, 1988))

Thirty years before he became Prime Minister, Disraeli wrote a novel called Coningsby. ... About halfway through the story, Disraeli's hero spends a few days in Manchester, and here are the thoughts which the Manchester of 1844 called to his mind:

> *A great city, whose image dwells in the memory of man, is the type of some great idea. Rome represents conquest; Faith hovers over the towers of Jerusalem; and Athens embodies the pre-eminent quality of the antique world, Art. ... What Art was to the ancient world, Science is to the modern: the distinctive faculty. ...*

What was so exciting about Manchester? Disraeli with his acute political and historical instinct understood that Manchester had done something unique and revolutionary. Only he was wrong to call it science. What Manchester had done was to invent the Industrial Revolution, a new style of life and work which began in that little country town about two hundred years ago and inexorably grew and spread out from there until it had turned the whole world upside down. Disraeli was the first politician to take the Industrial Revolution seriously, seeing it in its historical context as a social awakening as important as the intellectual awakening that occurred in Athens 2,300 years earlier. ...

Science did flourish in Manchester during the crucial formative years of the Industrial Revolution, but the relations between science and industry were not at all in accordance with Disraeli's ideas or with the ideas of later Marxist historians. ...

... The science which grew in that northern soil had a style different from the science of Athens, just as two hundred years later the music of the Beatles growing up in nearby Liverpool had a style different from the music of Mozart. The science of Athens emphasises ideas and theories; it tries to find unifying concepts which tie the universe together. The science of Manchester emphasises facts and things; it tries to explore and extend our knowledge of nature's diversity. ...

Manchester brought science out of the academies and gave it to the people. Manchester insolently repudiated the ancient prohibition, "Let nobody ignorant of geometry enter here,' which Plato is said to have inscribed over the door of his academy in Athens. ...

The discoveries of recent decades in particle physics have led us to place great emphasis on the concept of broken symmetry. The development of the universe from its earliest beginnings is regarded as a succession of symmetry-breakings. As it emerges from the moment of creation in the Big Bang, the universe is completely symmetrical and featureless. As it cools to lower and lower temperatures, it breaks one symmetry after another, allowing more and more diversity of structure to come into existence. The phenomenon of life also fits naturally into this picture. Life too is a symmetry-breaking. In the beginning a homogeneous ocean somehow differentiated itself into cells and animalcules, predators and prey. Later on, a homogeneous population of apes differentiated itself into languages and cultures, arts and sciences and religions. Every time a symmetry is broken, new levels of diversity and creativity become possible. It may be that the nature of our universe and the nature of life are such that this process of diversification will have no end.

If this view of the universe as a steady progression of symmetry-breakings is valid, then Athens and Manchester fit in a natural way into the picture. The science of Athens, the science of Einstein, tries to find the underlying unifying principles of the universe by looking for hidden symmetries. Einstein's general relativity showed for the first time the enormous power of mathematical symmetry as a tool of discovery. Now we have reason to believe that the symmetry of the universe breaks ... and the laws of its behaviour become unified if we go back far enough into the past. Particle physics is at the moment at the threshold of a big new step in this direction with the construction of Grand Unified models of the strong and weak interactions. The details of the Grand Unified models are worked out by studying the dynamics and composition of the universe as it is presumed to have existed for an unimaginably small fraction of a second after its beginning. ...

In a similar fashion, the science of Manchester and of Rutherford, the science of the diversifiers, is an exploration of the universe oriented toward the future. The further we go into the future, the more diversity of natural structures we shall discover, and the more diversity of technological artifice we shall create. ... Unifiers are people whose driving passion is to find general principles which will explain everything. They are happy if they can leave the universe looking a little simpler than they found it. Diversifiers are people whose passion is to explore details. They are in love with the heterogeneity of nature and they agree with the saying, "Le bon Dieu aime les détails." They are happy if they leave the universe a little more complicated than they found it.

Now it is generally true that the very greatest scientists in each discipline are unifiers. This is especially true in physics. Newton and Einstein were supreme as unifiers. The great triumphs of physics have been triumphs of unification. We almost take it for granted that the road of progress in physics will be a wider and wider unification bringing more and more phenomena within the scope of a few fundamental principles. Einstein was so confident of the corectness of this road of unification that at the end of his life he took almost no interest in the experimental discoveries which were then beginning to make the world of physics more complicated. It is difficult to find among physicists any serious voices in opposition to unification. ...

In biology the roles are reversed. A very few of the greatest biologists are unifiers. Darwin was a unifier, consciously seeing himself as achieving for biology the unification which Newton had achieved for physics. Darwin succeeded in encompassing the entire organic world within his theory of evolution. But the organic world remains fundamentally diverse. Diversity is the essence of life, and the essential achievement of Darwin's theory was to give intellectual coherence to that diversity. ... Darwin had no peer and no successor. ...

APPENDIX IX

Approaches to Science in Industry

by K. Alex Müller*

(* Professor Alex Müller received the Nobel Prize in Physics in 1987, together with J. Georg Bednorz, for the discovery of High Temperature Superconductivity).

Projects in Industry, especially IBM

I should like to expose the way research and development (R&D) is done in IBM.

In IBM, R&D is carried out in both the research and production divisions. One distinguishes three categories: sciences, advanced projects, and development. In the sciences, efforts are undertaken to increase the knowledge and deepen the understanding in areas possibly, but not necessarily, of importance to the company; to name just some of them: mathematics, especially the applied branch, computer sciences, of course, physics, materials sciences, and also certain areas of chemistry ranging from anorganics to polymers. Results obtained in these areas are normally published in the appropriate journals and presented at conferences and symposia.

There is a clear-cut distinction between advanced projects and development. The former are of high-risk character and not time-limited, i.e. they are terminated by either success or in the opposite case if one can show that they have no future. The Josephson computer project is an example of the latter case, as the Zurich Laboratory group could establish that it was not possible technically to create the appropriate memory chip with this device and reasonable tolerances. Development projects, on the other hand, are of low risk and time-limited. They have a definite goal in the form of a product. Usually development is carried out in the Production Divisions at various levels of sophistication, whereas advanced projects and sciences are pursued in the Research Division, which at present totals 3500 employees.

The categorisations outlined above are however not at all strict. Sometimes development is carried out in the Research Division, and at other times quite fundamental insights are gained at a laboratory in a production facility. A recent example of the former is the local-area network called "Token Ring" developed at the Laboratory in Rüschlikon, Switzerland, which belongs to IBM's U.S. domestic Research Division. This Token Ring is now an IBM product. Of course, in such a case, the issue of technology transfer from research to production is posed. This is not specific to IBM, but can be found in all larger companies. Recalling from my years at Battelle Memorial Institute, novel solutions found under contract research for specific medium-size companies had to overcome the reservations of "not invented here" at middle-echelon levels of the respective company.

Under the leadership of Dr. R. Gomory, then the Director of Research, IBM adopted a policy which successfully helps in technology transfer and innovation: staff members of the production divisions spend longer periods of time in appropriate departments of the research division and, vice versa, individual people or whole groups from research are assigned to particular production divisions. This substantially reduces the barriers in the transfer process. To assess the quality of research, for a number of years, a committee led by the IBM Chief Scientist visited about half a dozen IBM locations each year. The committee consists of two to three IBMers, usually Fellows of the company, and half a dozen well-known scientists from universities.

To decouple research to a certain degree from the pressures inherent in product manufacture, the director of research usually reports to the highest executive of the company, until recently to the president, now to the senior vice president and chief scientist, who in turn reports to the president. However, this decoupling is not of a strict nature. In case of an alarming situation in the company, a substantial number of the research division staff may become involved in understanding and remedying the difficulties, partially at the production line, as was the case when the yield of the newly introduced multilayer ceramics was very low. Multilayer ceramics are used to interconnect up to a hundred VLSI chips. Another example was the sensitivity of the electronic components to radioactivity, and other such situations may arise in the future.

Industrial, University and Government Laboratories

In the electronics industry, companies comparable in size to IBM all invest substantially in research and development, be they in Europe, the USA or Japan. Although the designation of the efforts may vary nominally, the scope and emphasis as well as the amount spent for research in comparison to that for development will not differ too much. In stating this, I have in mind vital and healthy R&D. However, it cannot be overlooked that in both Europe and the USA there are companies which once were leaders in R&D but are now receding in this respect. Partly they abandoned sciences or they lack in innovative spirit. To be vital in the latter is a matter of utmost importance and of substantial concern to management. The approaches and evaluation of success in research vary from company to company. From this also the self-understanding and what I would call the "local" culture, taste and ethics of the staff members, their behaviour towards their colleagues and in their groups are distinctly different.

In the above, I alluded to the fact that even larger companies prefer supporting the advanced-project, or even only the development, over the science aspect. On not too long a timescale, this does not preclude innovativeness to generate competitive products on the marketplace. Small companies are usually restricted to such a policy owing to their limited R&D budgets. Help in this respect can come from government contracts or institutes like the Battelle Memorial which have expensive equipment from their own resources at their disposal. However, only a sizeable science department leads to breakthroughs like the transistor or the maser/laser, which after development times of the order of decades changed technology altogether.

From what I have just said, one may think that a substantial manpower effort is needed to initiate such impressive developments. Here, one has to be considerably more differentiating: the important innovations are achieved by one person or a small group of two or three. This was true for the transistor, the maser principle, or, much earlier, even the electron microscope, the radar idea, and, more recently, the tunneling microscope and the high-T_c superconductive oxides. However, I have to add immediately that in all these cases, even with the radar klystron at Stanford, the environment in which these achievements came about was very important! With this I mean the high scientific level and expertise of a research centre or laboratory, for which the hiring of excellent young staff members is crucial. Their interaction as well as that with visitors for shorter and longer periods of time and relations to high-class university institutions are essential.

Examples of centres with excellence are, as just mentioned, major well-known universities in the USA, Japan and Europe. Others are national and supranational centres, like the high-field magnetic laboratory in Grenoble, where the quantum Hall effect was discovered. Media people have frequently asked whether in materials research there was a difference of approaches between universities and industry. This is certainly not the case with regard to quality as such, when looking at the best laboratories. However, in the science laboratories of larger industrial companies the structure is more "amorphous" , at least in our company, and in a way also more liberal. Therefore interactions between scientists of different departments are rather easy and creative. For example, Dr. Bednorz and I were not in the same research group when we worked together on the copper-oxide ceramics. Despite the democratization since 1968, university groups are more dominated by the professor leading the group, and thus tend to be tied to a specific field. This, of course, has to be so because one of the goals is the instruction of the students in order to lead them to academic maturity, i.e. a degree. So it is quite natural that the theme of a thesis will be chosen without too high a risk, from the field of interest of the research group.

The facilities dedicated to materials research, such as the magnet laboratory at Grenoble or reactor and synchrotron facilities to carry out neutron or X-ray diffraction experiments, are usually at the disposal of university staff people. Thus, they represent a possibility to counterbalance the relatively more closed university structure as compared to industry. At such centres, here I mention the facilities in

Grenoble and Desy in Hamburg in Europe, or in the USA , the Brookhaven National Laboratory, it is exactly this immense opportunity to meet and discuss with colleagues and experts from other fields and cultures, which makes them so valuable and attractive. This is comparable to the large research centres of industry. One also has to include the "offsprings"of former nuclear research centres, such as Los Alamos in the USA or Jülich in Germany, which have recently been redirected more towards materials research.

The specific projects in such government facilities dedicated to materials science are comparable to what is spent at industrial centres. In total budget and manpower, their size is comparable to that of the research divisions of large companies. This is also true for the high-energy centres until recently. But the emphasis of the latter is quite different, especially the specific experiments are undertaken at costs larger by a factor of one or two orders of magnitude; a ratio which is also reflected by the number of people involved. Often several university groups cooperate in such experiments, which requires planning and coordination over several years. Thus, the personal freedom of the staff involved can become quite restricted. From this, there appears an affinity of such undertakings with the larger development efforts in industry. Therefore, it is not surprising that staff members from say, CERN, transfer to industry and vice versa, or that the directors of industrial research and of high-energy centres meet and consult.

APPENDIX X

"Technologies of the Twenty-First Century"

(From "The Twenty-First Century", Chapter 16 of Infinite in All Directions by Freeman Dyson (Harper and Row, New York, 1988))

Technology is a gift of God. After the gift of life it is perhaps the greatest of God's gifts. It is the mother of civilizations, of arts and of sciences. ... Technology continues to grow and to liberate mankind from the constraints of the past. ...

The most revolutionary aspect of technology is its mobility. Anybody can learn it. It jumps easily over barriers of race and language. And its mobility is still increasing. The new technology of microchips and computer software is learned much faster than the old technology of coal and iron. It took three generations of misery for the older industrial countries to master the technology of coal and iron. The new industrial countries of East Asia, South Korea and Singapore and Taiwan, mastered the new technology and made the jump from poverty to wealth in a single generation. That is the reason why I call the new technology a technology of hope. It offers to the poor of the Earth a short-cut to wealth, a way of getting rich by cleverness rather than by back-breaking labor. ... If we view the world with a certain largeness of view, we see technology as the gift of God which may make it possible for us to live at peace with our neighbors on this crowded planet.

... If we are to lead the world toward a hopeful future, we must understand that technology is a part of the planetary environment, to be shared like air and water with the rest of mankind. To try to monopolize technology is as stupid as trying to monopolize air.

Technology as a liberating force in human affairs is more important than weapons. And that is why scientists speak about international political problems with an authority which goes far beyond their competence as bomb-builders. Forty years ago, scientists became suddenly influential in political life because they were the only people who knew how to make bombs. Today we can claim political influence for a better reason. We claim influence because we have practical experience in operating a genuinely international enterprise. ... Unlike our political leaders, we have first-hand knowledge of a business which is not merely multinational but in its nature international. ... As scientists we work every day in an international community. ... That is why we are appalled by the narrow-mindedness and ignorance of our political leaders. ...

Here are my guesses for the dominant new technologies of the next seventy years. ... The first is molecular biology, the science of genetics and cellular physiology at the molecular level. The second is neurophysiology, the science of complex information-processing networks and brains. The third is space physics, the exploration of the solar system and the physical environment of the Earth. Each of these areas of science is likely to give rise to a profound revolution in technology. The names of the new technologies are genetic engineering, artificial intelligence and space colonization. ...

Genetic engineering is already established as a tool of manufacture in the pharmaceutical industry. Bacteria can be infected with alien genes and cloned to produce in quantity the proteins which the alien genes specify. ... Genetic engineering makes economic sense today only for producing drugs which can be sold at a high unit price. ... Biological reactions are slow and require large volumes to produce substantial through-put of products. For this reason, genetic engineering will not replace conventional chemistry so long as the genetically engineered creatures are confined in tanks and retorts.

... Genetic engineering will ... become profitable for large-scale chemical production when the growing and harvesting of genetically engineered species can be moved outdoors. Chemical industry will then no longer be clearly distinguishable from agriculture. Crop plants will be engineered to produce food or to produce industrial chemicals according to demand. ...

... In the end, the genetic engineering revolution will act as a great equalizer, allowing rich and poor countries alike to make productive use of their land. A suitably engineered biological community will be able to produce almost any desired chemical from air, rock, water and sunshine. ...

The second technological revolution is artificial intelligence. This revolution has already begun with the rapid development and proliferation of computers. ...

The third technological revolution which I see coming is the expansion of life's habitat from Earth into the solar system and beyond.

... [Ben Finney and Eric Jones] condense the whole of human history into four big steps. Step 1 was taken about four million years ago in East Africa. It was the step from the trees to open grassland. The new skills required for the change were walking and carrying. Step 2 was the move out of the warm, sunny climate of Africa to the more varied and generally hostile habitats of the remaining continents, Asia and Europe and America and Australia. This step began about 1 million years ago. The new skills required for it were hunting, firemaking and probably speech. Step 3 was the move from land out onto the open sea. This step began three thousand years ago and was taken first by the Polynesians, with the Europeans following hard on their heels. The new skills required were shipbuilding, navigation and science.

Step 4 is the step from Earth to the stars. ... The new skills required are to some extent already in hand: rocketry, radio communication, observation and analysis of remote objects. ... It will require genetic engineering, and probably artificial intelligence too. Genetic engineering to allow colonies of plants and animals to put down roots, to grow and spread in alien environments. Artificial intelligence to allow machines to go out ahead of life and prepare the ground for life's settlement. ... But this step, like the first three steps from trees to grassland, from Africa to the world, from land to sea, will not be finished within a century. ...

...Two new technologies of space propulsion which may flourish in the next century [are] laser propulsion and solar sails. A third new technology for propulsion is the mass-driver. ... The mass-driver is a long magnetic accelerator which pushes little buckets down a straight track. You put into the buckets any material which happens to be cheap and available. The contents of the buckets are thrown out into space at high speed. Like the exhaust of a rocket, they exert a thrust on the vehicle to which the mass-driver is attached. Unlike a rocket, the mass-driver can keep on running forever provided it is supplied with electric power. The Sun will supply enough power to keep a mass-driver running anywhere within the inner solar system. Ships propelled by mass-drivers would be an efficient and economical means of transport for voyagers moving around in the asteroid archipelago. ...

The next hundred years will be a period of transition between the metal-and-silicon technology of today and the enzyme-and-nerve technology of tomorrow. The enzyme-and-nerve technology will be the result of combining the tools of genetic engineering and artificial intelligence. ... When I think of the space technology of tomorrow, I think of three concrete images in particular. ... The Martian potato, the comet creeper and the space butterfly are merely symbols, intended, like the pictures in a medieval bestiary, to edify rather than to enlighten.

When life spreads out and diversifies in the universe, adapting itself to a spectrum of environments far wider than any one planet can encompass, the human species will one day find itself faced with the most momentous choice that we have had to make since the days when our ancestors came down from the trees in Africa and left their cousins the chimpanzees behind. We will have to choose, either to remain one species united by a common bodily shape as well as by a common history, or to let ourselves diversify as the other species of plants and animals will diversify. ... This is the great question which will soon be upon us. Fortunately, it is not the responsibility of this generation to answer it.

APPENDIX XI

"The Double-Edged Sword Called Technology"

(From Chapter 14 of The Privilege of Being a Physicist by Victor F. Weisskopf (W.H. Freeman and Company, New York, 1989)

During this century, there have been tremendous developments in science and technology. While these achievements were mostly created in Europe and America, they have now spread to all civilizations throughout the world. The values underlying this development have frequently been called into doubt. But during the last twenty years, these doubts have increased in intensity and fervour to such an extent that we now face a crisis. It is fashionable today to emphasize the shortcomings of scientific-industrial civilization and to de-emphasize its benefits. The industrialized world must therefore take stock of itself.

Technology, like science, sprang from an openness of mind toward individual phenomena, from a systematic study of the details of what is going on in nature. The first technical applications of such studies date back even further than the origins of the natural sciences. We find examples in the Greco-Roman period and in the early Middle Ages. The necessary spur was provided by the growth of cities and their interest in better methods of production of metallic utensils. It was not until technology made it possible to build measuring instruments that science could develop properly. Initially, then, the natural sciences were a consequence of technology.

Later on, science and technology became much more closely linked. The steam engine was by no means invented on the basis of scientific research. Quite the contrary: it gave impetus to research into the theory of heat. Possibly the first great achievements in which science and technology worked side by side involved the invention of the electric dynamo and motor, based on the discoveries of electric and magnetic phenomena of Ampere, Neumann, Faraday, and Maxwell. It is interesting to note, moreover, how short a time these technical developments took. Electric dynamos were constructed a little more than twenty years after the discovery of the connection between electricity and magnetism. Nowadays, progress is not much faster. For instance, the time which elapsed between the discovery of the neutron and the practical application of nuclear power was of the same order. There are more scientists and engineers today but the problems become more complicated. On average, these two factors balance each other.

Today, technology and science depend completely upon each other; they are in a symbiotic relationship. Technology cannot advance without science, nor science without technology.

Here is a brief outline of some essential steps of this symbiosis. Considering only the physical sciences, three great scientific discoveries were made during the nineteenth century: the existence of atoms and molecules, the nature of heat as a disordered motion of atoms, and the unity of electricity, magnetism, and optics. The theory of heat evolved from the steam engine; the development of electromagnetism and optics led to the electrical, optical, and communications industries; and, of course, the recognition of atoms and molecules brought the chemical industry into existence.

The twentieth century witnessed, in its first quarter, an ever growing insight into the structure of the atom by means of quantum mechanics. In parallel we say the development of electronic industries based upon a better understanding of the interactions between electrons and atoms. When the nature of the chemical bond was revealed by further applications of quantum mechanics to atomic and molecular dynamics, a deeper understanding of the structure of metals, crystals, and other materials was achieved. This led to an expansion of chemical industries and to the production of new materials. It finally brought about the invention of transistors and semiconductors on which the computer industry thrives.

The next scientific step into the deeper layers of matter was the penetration into the structure of the atomic nucleus. Nuclear physics has brought about the exploration of nuclear power and the applications of artificial radioactivity to medical purposes and materials testing. Biology, with its revelations of the chemical nature of the life process, has found many fruitful applications in medicine and in the chemical industry.

On the other hand, none of these scientific steps could have been taken without the help of technology. This is most obvious in more recent developments, that would have been impossible without the help of the latest achievements of electronics and other precision technology. I remind you of the complicated and sophisticated technology that goes into the construction of a modern accelerator.

This tremendous development was much wider and greater than ever expected. It underwent an exponential growth that we still witness in the recent development of computers and lasers. The astounding success of science and technology had a deep influence on the entire social fabric. Our society, our philosophy, and our thinking have been shaken to the core.

We begin with the effects on the structure of society. Technological development has brought about a pervasive social regrouping. It produced the working class and it thoroughly changed the world of agriculture. Formerly, more than 80 percent of all people worked on the land. Now, in the developed countries, it is only 4 percent or less - brought about entirely through mechanization and by the so-called green revolution. Traffic and transport have been completely transformed: from classic times until the nineteenth century, transport was by horse-drawn wagons; Virgil and Mozart used essentially the same means of transportation. Now, we can span the globe in a day or two.

Cities have grown, and a population explosion has taken place because of the successes of medical science, amounting to what one may call "death control," through improved hygiene and the eradication of epidemic diseases. When I was young there were only two billion people on this earth. Now there are nearly five billion.

Furthermore, because of advances in technology, it would be possible to stamp out hunger, feed people adequately, abolish need, contain epidemics, render strenuous physical labour unnecessary, and above all enable people to lead a substantially more comfortable life. Of course, these possibilities have by no means been realized everywhere, but they have been achieved to a considerable extent in the developed countries - western Europe, Japan, and the United States - but only to a small extent, if at all, in the third world. Please note, however that my enumeration consists of factors that make life easier, reduce need, and tear down obstacles that used to make life hard and difficult. Here we have a kind of double negative, the abolition of the burdens of life. I shall be returning to this particular point and its spiritual consequences.

Let me start with the positive side of the balance sheet of human development in the scientific-industrial age. In the middle of the nineteenth century and before - at the beginning of the industrial society - workers were ruthlessly exploited. There was child labour, a twelve-hour working day, and so forth. Today we have social legislation, trade unions, workers' rights, medical care, old-age care, all developed to varying degrees. In the West, and also in the East, we witness a certain humanization of the capitalistic industrial system. In the East, the private capitalist system has been dismantled in favour of state capitalism, but in both parts of our world industrial society has been humanized in essential ways. In my view, Europe is further advanced in this respect than the United States. In general, there are better social services, especially in the smaller countries such as the Netherlands, Austria, and Scandinavia. To some extent, social progress in these countries has come about because they have more homogeneous populations and because they are fairly small.

The situation in the third world, however, is considerably worse. The benefits of the industrial system are at a lower level and are not shared among different strata of the population. Although it is true that there are fewer countries under the domination of developed nations, the power has been transferred from foreign to indigenous "exploiters" without any major increase in general welfare. These countries must, in a few decades, catch up with what has taken the western world a century or more to achieve; this cannot be done without some crises and disasters. We observe a similar kind of nationalism, fanaticism, and jingoism pervading the developed world in previous periods. I do not wish to pursue these problems here, although they are extremely important to the future of our world.

We now come to the unsolved problems, the negative side of the balance. What is involved here is pollution. There are two categories - material pollution and spiritual pollution. Let us begin with material pollution.

The expansion of technology over the surface of the globe has produced effects on nature that can no longer be neglected. Earlier, the regions and areas where technology changed the natural world for the worse or for the better were small, compared with the regions that remained entirely unaffected. The chalky plateau of Dalmatia, for example, was ruined by the Romans when they chopped down the forests, but that was only a small part of the earth's surface. Today, the entire surface of the earth is involved. We constantly increase the content of carbon dioxide in the air, we reduce forest areas, we pollute rivers and oceans, and we use up raw materials. Lately, some people assert that the use of nuclear power stations could produce global damage.

I am convinced that these questions, in the foreground of discussion nowadays, can be solved technically. It will not be easy and it will increase the cost of industrial production, but this is nothing new. Social progress, to which I referred earlier, also increased the costs of industrial production, and rightly so. Humanization of the industrial system was also expensive. For costs should correspond not only to what is needed to produce goods, but also to what is needed to correct possible damage to nature or the social sphere. Efforts must no longer be exclusively directed toward innovations and new inventions; they must also go to avoiding undesirable consequences. How can pollution be prevented? How can the production of carbon dioxide be decreased? How can the safety of nuclear power stations be increased? How can radioactive waste be safely disposed? How can we produce energy from means other than combustion of fossil fuels? How can we reduce energy consumption?

These problems are solvable, but only under certain conditions. One of these conditions is a stable population. We need birth control in order to offset death control that was introduced by medical advances. Another condition is a reasonably stable political situation, without irrational outbursts and conflicts nurtured by emotions and fanaticism. This will be very difficult to maintain in the third world, where there are understandable pressures for fast industrial development, without considering environmental costs.

We now come to spiritual pollution. We speak of progress. To be sure, the progress of scientific-technical culture has been immense. In the realm of science, we are on the threshold of entirely new, profound insights into what takes place in nature - the primeval big bang, or origin of the universe, the formation of the elements, the structure of matter. The fundamental forces that govern the world become known, and so do the molecular processes at the basis of life. The twentieth century will be known as the age in which humankind acquired its deepest insights into the workings and history of the natural world, if it will be able to avoid being remembered as the age of the great nuclear catastrophe.

On the technical side, as already mentioned, there exists the possibility of avoiding hunger, want, illness, and oppressive manual work. The world has become accessible to all through modern transport. The abolition of want has been reasonably successful in the developed countries. It is a double negative; it has freed humanity of burdens. Freed it for what? What does one do with one's life when one no longer has to fight for existence for twelve hours a day? The individual is thrown back upon himself and must find the meaning of his or her life. Work in the industrial complex is mechanical and secondary. It does not rest on the personal achievement of those working, but on that of the engineers who have invented and developed its methods. The average worker has little influence on the direction of the enterprise of which he is a part. What becomes of human dignity? Where is individual sense and purpose?

By and large, nonscientists are not inspired by scientific insights. What they understand of science nowadays is roughly this: because everything follows the laws of nature, we do not need a god. Science is appreciated mainly because of its technical applications. In part, this is the fault of scientists themselves. They have achieved great things, but they have not made sufficient efforts to convey the greatness and wonder of these ideas to their fellow beings in a comprehensible way. I believe that conveying these insights is possible, but it is a difficult task that is tackled by far too few gifted people. The situation is equally bad in respect to the great achievements of technology. It is true that the proliferation of science fiction helps in some ways to excite a certain enthusiasm for the wonders of technology. (Science fiction is a misnomer; most examples of it should be called technology fiction.) Still, prevalent reaction to technology consists in a certain accommodation to present levels that have made life more comfortable. But it also expresses the fear that further innovations will lead to more deadly weapons and to the destruction of the environment.

Can art and literature provide a sense of purpose to our lives? When art was still in the service of religion, it was no doubt generally comprehensible and acknowledged by the majority. When religion lost its influence, art acquired independence. It continued to be the expression of the great ideas of its time. But it was accessible only to an upper stratum of society. Where is the art that concerns itself with the ideas of science and technology? Surely it is the task of artists to bring the great ideas of our time closer to the public. I believe that Sinclair Lewis's *Arrowsmith* is the last great novel that describes the excitement of scientific research.

For most people, however, neither art nor science is of deep significance. When the most important needs have been provided for, the content of life generally amounts only to a desire for passive entertainment such as viewing TV or driving a car, and the like. What is sorely lacking is a fulfilled, creative content of life for the population at large.

At the beginning of this essay, I raised the question whether the present crisis represents the end of the scientific-technical culture or whether it is merely a transitional crisis from a relentless drive to a more mature and calmer period. I cannot answer this question, but I know that the optimistic interpretation rests on the achievement of *three* basic aims. The first is the abolition of nuclear weapons, so that this terrible sword of Damocles no longer hangs over mankind.

The second is the prevention of environmental catastrophes. Technical creativity should be redirected away from commercial and military tasks and toward environmental problems, in order to arrive at a pollution-free technology.

The third aim is the provision of a creative and purposeful life for the majority, not only for the few.

What we need is a broader sense of complementary attitudes. Scientific, ethical, artistic, and religious approaches are not contradictory, they complement each other. Here, today's educational system faces an important task. It needs reform in many ways. Regarding the problems raised in this essay, it should include teaching tolerance and enthusiasm for the variety of human endeavours. This is not ethical relativism or the denial of values. On the contrary, it would derive ethical principles and a system of values from many sources. Education on all levels, from elementary school to college, should foster an attitude of openness and understanding for different complementary approaches to the realities of life. Such an attitude is one of the preconditions for the survival of our civilization.

APPENDIX XII

Unequal Treaties

by Alan L. Mackay

(Paper presented to the Workshop on Increasing Flow of Scientific Literature to Third World Institutions, 31 October - 1 November 1988, Trieste, Italy)

Most people familiar with the Third World are also familiar with the Unequal Treaties which are often still the de fact basis for the division of the world into often rather curious nation states, constructed on the basis of former colonial boundaries, rather than on rational economic or cultural characteristics. It is not necessary to examine the reasons for which such treaties were made. Usually one of the parties was just not in a position to press for fairer terms. There are standard mathematical examinations of the statistics of what happens if a person A, with a capital of one million, gambles with a person B, having a capital of ten. What are the probabilities that A will ruin B? Marx discusses the similar position of people who have only their labour power to sell.

I want now to point out the unequal position of scientific authors with respect to publishers. This paper was provoked by receiving a request, from a major international publisher of scientific journals and books, for the transfer of copyright. I think that the terms of this "agreement" are so scandalous that it is necessary to mount a campaign for more equal terms and to enlist the aid of scientific organisations to present a more united front in the face of exploitation. This company also has the nerve to advertise themselves as "Fighting against copyright erosion".

1) There is, of course, a long history of publishers acquiring the copyright of valuable productions in exchange for a small one-off payment. Conan Doyle is believed to have disposed of the British copyright of "A Study on Scarlet" to John Murray for something less than $20. He says that there was no American copyright in 1887 when the stories were written.

2) In following the career of scientist it is necessary to build up a corpus of publications. John Ziman has discussed the nature of science as "public knowledge". What is not published is not public knowledge and the slogan "publish or perish" has a substantial basis. A scientist has to get his stuff published however disadvantageous the terms.

3) The publishing of scientific papers is partly in the hands of scientific societies, and thus under professional control, but an increasingly large class of journals is operated purely for profit by commercial publishers who have experienced an increasing trend towards aggregation.

4) Scientific literature is distinguished from "literature" in that it has direct economic and commercial significance. It affects the private ownership of discoveries through the patent system. It affects directly the careers of individuals. The scientific literature ha thus an excess monetary value in that the institutions of science cannot afford to be ignorant of any relevant publications. After 1945 it was discovered by various publishers that institutions would still buy scientific publications even if the prices were grossly increased. There are parallels with the cornering of the world market in such necessities as quinine.

Scientific publications emanating from Third World countries, where their production is cheaper, have often been cornered by the allocation of exclusive distribution rights to major publishers, so that enormous mark-ups were, and still are, encountered.

5) The provisions of copyright, on the whole, do not work in favour of the individual scientist. His major interest is in seeing his writings disseminated as widely as possible and he is only rarely on the other side and in the position of having written a best-selling textbook from which he may be in the position to make money, comparable to that more often gained by the author of a popular work of literature.

The individual scientist has strong interests in being able to copy for his own use whatever materials he can find relevant to his work. Correspondingly, authors of scientific papers are swamped by reprint requests from Eastern Europe, where the finance of research is inadequate for buying necessary journals. In principle, universities in Britain at least, make provision for the costs of buying reprints of papers by their staffs, but increasingly the enormous cost of buying reprints from publishers, compared with their production by offset or Xeroxing, favours the latter process.

6) I have had the pleasant experience of working in South Korea before that country subscribed to the International Copyright Convention. The local book pirates produced nicely printed and bound copies of all books which they thought they could sell. Their costs were those of production and their datum was how much it cost to make a Xerox copy of a book. If they could not copy it cheaper, then it was not worth printing. Students habitually would borrow a textbook from a library, take it to the local Xeroxing shop at lunchtime and in the evening collect a copy, double sided and with instant binding for about £5. Copies of the major series of texts were widely available in departmental libraries. When I see that individual Korean students have three times as many books as British students I am not, even as a textbook author, sorry for the publishers. There are, of course, also many legitimately licenced copies of standard textbooks.

On top of this, many European and American publishers get their printing done in Korea and other places where skilled labour is cheaper. Where does the difference between the price of the Korean and of the official edition go?

7) My own experience in producing books has been mostly unsatisfactory. For example, I approached 20 publishers before getting one to take on a book, and was thus in no position to negotiate from strength. Insofar as the compilation was my own work, the copyright does not belong to me but to the publisher. In the unequal treaty the publishers included a 25% kickback to one of their own employees for editing. Copies were sold at £2 to dealers in America for retail at $14 and so on. The scientific author is a commodity like a footballer, to be transferred or not without his consent.

We might note too, that an estimate of the number of copies sold depends totally on the honesty of the publisher and that the author has no means of checking the figures with which he is provided.

8) Having acquired the copyright of a scientific paper for a journal it is open to the publisher to produce a collection of such papers to sell as a book without having to pay anything at all or even having to ask the authors.

9) It is has become normal practice that the editors of scientific journals should seek the opinions of referees on papers submitted to them. Refereeing is highly skilled work, taking considerable time. Yet, commercial publishers of journals expect that the profession at large should do this work for them free, without payment.

It is legitimate that members of a learned society which produces a journal for the promotion of the mutual interests of the profession should participate in refereeing to keep a uniformly high standard for the profession. All benefit by such practices.

However, the academic profession is under pressure from the government to market education and research as commodities and it is no longer justifiable to give away a substantial section of their product as was done in happier times.

Conclusions

I consider, therefore, that the scientific profession is grossly exploited by commercial publishers, both of books and of journals and that it is necessary to reverse this trend by arranging that cooperative associations of scientists such as the numerous learned societies, should be able to publish without excessive mark-ups.

I would recommend that the Third World Academy of Sciences should publish books and journals directly in the Third World, using connections with low cost publishers and printers and should aim to force down book prices in the traditional free-market way.

There is a considerable disparity between the strict legal position and actual practice as regards the law of copyright. Nominally, fees for the production of single copies of a paper should be paid to the publisher but these do not appear to be forwarded to the authors.

I would like to see scientific organisations such as ICSU, various professional societies, national academies and bodies financing research, recommend a model form of copyright transfer as appropriate for the authors of papers to sign. This would, I suggest, give an exclusive licence to the publisher (in the case of a journal article), for about two years and the copyright and other rights would remain with the author.

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APPENDIX XIII

Japanese Industrial Development and Policies for Science and Technology

by Toshio Shishido
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Summary: Two important factors that contributed to Japan's economic success were government investment in industrial development and the early recognition that a good educational system is a prerequisite to technological progress. Government policies promoted the importation of technologies from Europe and North America and encouraged the education of students abroad. This facilitated the rapid development of Japanese industry and the adaptation of foreign technologies to local conditions. Many of the methods used to develop industry in Japan could be used to advantage in developing countries today.

In this article I describe Japan's industrial development and Japanese policies for science and technology. In the process of industrialization and modernization, Japan imported many new technologies in a wide variety of fields and at the same time made great efforts to improve these technologies and adapt them to local conditions. The success of these efforts depended on many factors, the most important of which were the education of the general population and government initiative and support.

The development of industry in Japan over the last 100 years can be divided into four stages. During the first stage, which lasted fro the mid-1800s until the end of the 19th century, the metal, chemical, and machine industries became increasingly dependent on imports. The technological development of these industries, and of the light industries that produced such important export items as textiles, was therefore limited until the beginning of the second stage in about 1900. The third stage of development began after World War II, when Japan had to undergo a rapid development process to catch up with the advanced technology of the West. By the early 1970s the level of technology in Japan had surpassed that in Europe and reached about the same level as in the United States. Now, in the fourth stage of development, Japan's attention is turning from imitative to creative technology.

Stage I. Policies for Promoting Industries

The Meiji government (1868 to 1912) recognized that increased production and the promotion of industries were essential for establishing a solid economic foundation for the construction of a modern state. The immediate target of its policies was the curtailment of imports and the promotion of exports, with greater emphasis on the former. With the opening of the country to foreign trade, foreign products poured into the domestic market, putting pressure on the domestic cotton-yarn industry as well as other industries, and causing a chronic deficit in the international balance of payments.

To counter this trend, the introduction of modern industry was urgently called for. However, there was little private capital available, so that nothing short of direct investment by the government could accomplish the desired objectives. Since the government aimed at encouraging the private sector to follow its example, it made direct investments covering the operations of its own factories, the construction of railways, the exploitation of mines, and the management of experimental stations.

The Ministry of Engineering, created in 1870, was charged with the responsibility for encouraging the development of many industries and running the mines, railways, and communications. During the ensuing 15 years it operated the government-owned factories and mines, many of them expropriated from the former Tokugawa Shogunate and the feudal lords. Tomioka Spinning, for instance, was established in 1872 by the government; it was equipped with French-made spinning machines and was operated by French techniques.

In this manner, the Meiji government succeeded in introducing foreign industries and technology through the examples of its own direct activities. Although its accomplishments may have fallen short of its desired objectives, the Meiji government undoubtedly played an important role in the modernization of private industries and technology (1).

The industrial technology of the early Meiji era, having been almost wholly independent on technology imported from Europe and North America, had little affinity with contemporary indigenous production techniques. This technological dependence took the form not only of employing foreign engineers and craftsmen and importing plants, machinery, and industrial raw materials, but also of importing such elementary techniques as the making of bricks. This was found necessary on account of the lack of a technological tradition on which to draw for the development of modern industries. Having been transplanted to state-run factories with total disregard of its economic justifiability, such technology found little direct application in the private sector of industry.

There was nevertheless a substantial gain, since local employees working in these state-run factories acquired skills in operating various machines and transferred these skills to the private factories that were subsequently built. Thus the privately owned spinning mills built in the 1880s imported their machinery from England and other Western European countries but were operated by Japanese workers who had been trained under the direction of foreign technicians, in some cases to such a high level that they in turn were qualified to become instructors. In a similar fashion, large shipyards become training centers for shipbuilding engineers, and other technologies of foreign origin also were introduced and diffused into local industries in the later 1880s (2).

Transfer to private ownership. Because of fluctuations in business and bureaucratic inefficiency, the government's business undertakings were unable to avoid running into deficit. They were therefore gradually transferred to private ownership. Nevertheless, the government recognized the need of these enterprises for protection and maintained a vigilant surveillance over them. As they gained in self-reliance, the government gradually reduced intervention in their management and, after 1897, switched to a less direct and more modern type of protectionism. By early 1890, the spinning industry and several others had established themselves entirely with private capital.

Industry in Japan made great strides after the Sino-Japanese War (1894 to 1895), and during the ensuing years until the Russo-Japanese War (1904 to 1905) the slogan "increase of production and promotion of industries" was replaced by that of "postwar management", which embraced all spheres of national policy. Implicit in this slogan were stepped-up armaments, the development of education, and a well-defined industrial policy, one of whose manifestations was the series of war factories that emerged after the Sino-Japanese War. The expanding requirements for armaments led to large demands for strategic material of all kinds, including rolling stock and ships. However, deciding that the creation of heavy industries adequate to meet such large demands could not, and should not, be left to private capital, the government again invested in the heavy industries by way of direct ownership and management. The Yawata Iron Works, decreed in 1896 and established in 1901 by the government, was typical of such industries.

Early administrative structure for scientific and technological research. Scientific and technological research agencies were at first systematically organized in the respective administrative agencies of the state, with the creation of private organizations for scientific and technological research coming about rather later. From 1868 to about 1885, Japan depended entirely on foreigners for scientific and academic guidance. Thus nearly all the teachers in the higher scientific and technological educational institutions were foreigners invited and employed by Japanese authorities. But as time went on, they were gradually replaced by Japanese scholars who had studied abroad or had received scientific training under foreign teachers, and who then initiated their own original courses of study. An early example of this new regime is represented by the Earthquake Prevention Research Council, established in 1892, all of whose personnel were Japanese.

Stage 2. Rationalization Policy for Industry

Drastic changes in the industrial structure of Japan were effected by the policies of the Meiji government. A landmark was reached in 1919, when the output of industry for the first time outstripped that of agriculture. The structural changes accelerated the attainment of self-sufficiency in technology, therefore consolidating the foundations of the modern industries. During World War I, when the introduction of foreign technology was abruptly suspended, the government made a determined effort to establish and realign state-run research laboratories serving manufacturing industries, and at the same time gave friendly consideration to the views and proposals of private scientists and engineers relative to the opening up of engineering institutes.

In an effort to devise an effective industrial policy, the government enlisted academicians and businessmen to form research councils in various fields. The councils or boards appointed by the Ministry of Agriculture and Commerce (and then by the Ministry of Commerce and Industry) included the Supreme Council of Agriculture, Commerce and Industry (1896), the Production Research Council (1910), the Economic Research Council (1916), the Temporary National Economic Research Council (1918), the Council of Commerce and Industry (1927), and Temporary Industrial Council. The first of these - the Council of Agriculture, Commerce and Industry - was associated with the deliberations leading to the Factory Act, and the Production Research Council was instrumental in recommending to the government in 1912 various measures designed to develop industries.

The activities of these councils helped to make the government's industrial policies truly effective; they dealt with such questions as reduction of the price of industrial salt; development of hydro-electric power; promotion of technical education; additions to the curriculum of engineering high schools of courses related to special industries; expansion and reinforcement of state-run industrial experiment stations; and encouragement of the manufacture of machinery. Similarly, the Research Council of the Chemical Industry recommended measures for fostering the soda industry and subsidies for the tar-refining industry and for the development of research in the electrochemical industry. It also advocated priority for the physical sciences along with the establishment of a chemical research laboratory. Moved by their recommendations, the government established a chemical and physical research laboratory in 1917.

Realizing the importance of orienting more research toward technological development to compensate for the cutting off of technology imports during the war, the Ministry of Agriculture and Commerce, rather than simply expanding the Industrial Laboratory, set up a number of new industrial research institutes. These included the (temporary) Nitrogen Laboratory (1918), Osaka Industrial Laboratory (1918), Porcelain Laboratory (1919) and the Monopoly Bureau's Central Laboratory (1920). During the same period, the Ministry of Communications established the Ship Equipment Inspection Station in 1916, and transformed its Electro-Technical Bureau into an independent agency as the Electro-Technical Laboratory.

The Physico-Chemical Research Institute was established in 1917 with a government subsidy and contributions from industrial circles, but its financial foundation was not really stable. Nevertheless a liberal atmosphere, rarely encountered in universities, prevailed in the institute's organization and operation. Active interchange between the different research branches was encouraged, and the institute was managed under a basic policy calling for a careful selection of priority research projects to receive financial support and for an extension of joint research activities. As a consequence, many of the studies accomplished earned high international esteem. On the technological side alone, the successful results included Masatoshi Ohkochi's piston ring, Umetaro Suzuki's synthetic sake (Japanese rice wine), Yosei Suzuki's Ultramin (textile finishing agent), and Kotaro Honda's magnetic steel. Two Japanese Nobel Prize winners, moreover, were formerly members of the staff of this institute.

Besides these research agencies, institutes dealing with aviation and metals were set up in the Tokyo Imperial University and Tohoku Imperial University, respectively, around 1920. Thus a tradition was built up of attaching importance to basic studies. Since then, the practice of establishing research institutes in universities has been continued, and by 1968 there were about 200 institutes attached to national universities.

Stage 3. Catching up with Advanced Technology

After recovering from the ruinous conditions of the postwar years, Japanese industry in about 1955 was able to exceed the prewar level of production. This recovery was achieved through expansion of the basic industries that had completely modernized their production facilities during the early 1950s; it was further consolidated by the development of new industries such as synthetic chemicals, petrochemicals, and electronics.

Underlying these achievements were government policies promoting domestic industry. At the same time, the importation of foreign technology was highly encouraged, and entered into every branch of industry. The cost of imported technology during 1979 amounted to 13 times the cost in 1956. Thus Japan's technological recovery owed much to imported technology. The assimilation of this technology depended on a certain mature technological base that was, in turn, instrumental in reducing imports. The total sales of products derived directly from imported technology in early 1970 accounted for more than 30 percent of the total sales of the entire industry of Japan, and about 20 percent of the new products and technology developed during the years 1957 to 1961 were based on imported technology (3). Since 1965, moreover, imported technology has contributed increasingly to the production of plants, installations, and consumer goods for export (4).

Whereas in 1955 more than 50 percent of the technology imported had been developed before or during World War II, in the 1960s the greater part dated from after the war (5). Thus the industrial processes used in Japan were catching up with those of advanced Western countries. The importation of perfected foreign technology in the past obviated the risks and uncertainties inherent in the development of original technology, and provided a rapid and effective method of enhancing the technological level of Japanese industries.

Policies for the introduction of foreign technologies. The door permitting the entry of foreign technologies, which had been closed since the war years, was reopened in 1950, when the government enacted two laws dealing, respectively, with the introduction of foreign capital and with foreign exchange and trade control. These laws were designed to assist the postwar rehabilitation of the Japanese economy. Safeguards were included in the form of stipulations that such foreign technology should contribute to the improvement of the international balance of payments, and the corresponding policy on foreign exchange involved control of the influx of foreign capital. Paradoxically, this restrictive aspect actually helped to attract foreign holders to technology, and resulted in the selective importation of foreign technologies of such high quality as to warrant their cost in external payments. From 1965 onward, moreover, substantial payments were received for technology exported from Japan.

Of the technology imported, some 80 percent was related to the machinery and chemical industries (6). As a result, production in those industries increased markedly in the latter half of the 1950s. In 1960 the value of production derived from imported technology and allocated to domestic consumption equaled the total imports as calculated on the basis of the customs clearance (7). However, the export of goods produced by imported technology still remained at a comparatively low level in 1960. Japan caught up with American standards in many spheres of technology in 1970, and was able to start selling Japanese commodities, turned out by modern industrial complexes, at relatively low prices in other countries.

Stage 4. From Imitative to Creative Technology

According to estimations made by the Japan Productivity Center, the labor productivity (added value base) of Japanese steel industries exceeded that of the United States in about 1973. Labor productivity in the electric appliance industries became superior in the mid-1970s, and in the automobile industries labor productivity is likely to exceed that of the United States in the 1980s. This means that technology in Japan is already on the same level as that in the United States and has surpassed that in the European nations. The total balance of payment for technology is still unfavorable to Japan. However, when the transactions are limited to patents and know-how contracted in a single year, since 1977 Japanese technology exports have exceeded the technology imports. The receipt (export) from newly contracted patents in 1979 was almost double the payment for imported technology newly contracted in the same year. Thus Japan is now an exporter of technology (8).

Higher productivity as well as good-quality products were the secrets of Japan's economic performance after the oil crisis of 1972. Manufacturers in the United States are now eager to "learn the Japanese way," and fear that selling technology to the Japanese may boomerang, particularly in the fields of electronics and genetic engineering.

Japanese economic expansion, which relied heavily on imported technology, may soon be affected by a technology embargo. There is a national consensus that Japan should change her policies for science and technology from emphasizing imitation to promoting invention. Investment for research and development in Japan increased at an average annual rate of 16 percent in the 1970s, and its ratio to gross national product increased from 1.4 to 1.8 percent. The government intends to increase this rate to 2.5 percent in the mid-1980s.

Higher productivity in Japan than the United States has been reached by the use of applied technologies, with special attention being paid to the areas of automation and robots, as well as quality control. Developing originality is a new experience for Japan. Investment in R&D is not the only factor that will determine the country's new technological developments. Japan will also have to put more effort into developing new educational systems that will increase the human resources adaptable to creativeness.

The government is now declaring that Japan will become a technology-oriented state rather than a trade-oriented state rather than a trade-oriented state. National and social demands for new technologies will include:

1) Substituting other sources of energy for oil, which will include development of solar cells, high-efficiency gas turbines, and biomass.

2) Developing computer technology with the use of a combination of electronics and mechanics, as in industrial robots.

3) Investigating potentially useful materials such as new ceramics and carbon fibers.

4) Promoting research in the life sciences, especially genetic engineering.

Two-thirds of Japan's R&D is now done by the private sector on commercial projects. The government will now have to take more responsibility for R&D of basic technology.

Japan's Advantages in Technological Development

To appreciate Japan's ability for technological development it is necessary to consider not only the country's policies but also her historical and cultural background.

Centralized political system and sense of unity. When challenged from outside, the Japanese have a strong sense of unity, reflecting their long history as one race and one culture. Even at the beginning of the Edo era about 370 years ago, the Japanese political system was highly centralized, being governed by a shogunate. With such a homogeneous society and centralized decision-making system, it has always been easy to get a national consensus on goals (9).

Utilization of the home market. The mere existence of a large home market, represented by a population of 30 million at the beginning of the industrial revolution, has encouraged the development of new products and manufacturing processes.

Accumulated capital. Capital accumulation is an essential prerequisite if technology is to be utilized in such a way as to generate effective production facilities and raise productivity. The particular nature of capital accumulation in the Japanese economy has been characterized by: (i) the high rate of accumulation; (ii) the great contribution made by personal savings; (iii) the direct use of accumulated capital in fields where it can help to increase productivity; and (iv) certain aspects of the banking system.

Coexistence of modern and traditional industries. Leaders of some of the developing countries are under the misapprehension that traditional customs inhibit the development of modernized industry and the introduction of new techniques. The Japanese, in contrast, have utilized their dual economy to their advantage. Some of the industrial sectors were quick to adopt Western ways, but others took much more time. Transportation, such as railways and ships, as well as modern industries such as iron and steel, cotton-spinning, beer brewing, and cement production, were quickly transformed by labor-saving and capital-intensive technology. In the consumer and distribution sectors of Japan, however, westernization was greatly delayed. Although cotton-spinning was modernized, the textile industry remained largely as a side business of farmers. In the case of raw silk, which was Japan's leading export until the 1920s, and the match industry, which had a considerable export volume, Western technologies were adapted to Japanese traditions. In this manner, capital costs were kept low and the industries could make use of cheap labor. Thus the transformation of modern industries into traditional ones was an important factor in our growing process (10).

The larger modernized enterprises absorbed a large part of the government's investment but also introduced labor-saving techniques. Thus the increasing rate at which labor was employed by these industries was moderate compared to the rapid growth of production. The increases in employment between 1890 and 1935 reveal that whereas modern industry absorbed 3.7 million workers, the traditional sector absorbed 7 million (11).

High standards of education. The transfer of technology on which Japan's industrialization has depended has been facilitated by the country's traditionally high educational standards. Even at the beginning of the Industrial Revolution in Japan, the level of education was considerably higher than that in many of the developing countries today (12).

That good education is a prerequisite to a country's technological progress was recognized early in our history, and government policy has always been designed to encourage the accumulation of technological education. According to a white paper published by Japan's Ministry of Education, the level of technological knowledge in 1960 was about 23 times the level in 1905.

Selection of appropriate technology. As a latecomer to industrialization, Japan had the particular advantage of being able to choose well-established technologies from already developed countries and thus save the costs of trial and error. However, in order to select the most suitable technologies for importation, Japan had to make full use of its development planning abilities and educational resources. As a result of government initiatives, Japan made great efforts to send students and technical missions abroad, and to invite foreign specialists for consultation. It was thus possible to select the most appropriate technologies on the basis of opinions of well-informed advisers (2).

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Who are the Copy Cats Now?

(From *The Economist*, 20-26 May 1989)

As Japan's technology catches up with America's, scientific knowledge has begun to flow in both directions. As a result, governments in both Japan and America must look for new ways to promote their science.

Japan is not just an exporter of cars and video-recorders; it is becoming an exporter of ideas as well. As the charts show, it is no longer merely a borrower of other people's technology. The first chart maps trends in the way Japan's businesses buy foreign technology - through licences, patent fees, royalties and the like. Payments made by Japan have risen over the past two decades (from \$2.7 billion in 1970 to \$3 billion in 1985 in constant prices). But in the 1980s Japanese firms have also begun to earn handsome sums in the same way. In relative terms, receipts rose far more, from \$373m to \$898m in 1970-1985. (Japan also now spends less of its research and development budget on foreign ideas.)

The second chart displays some trends in the American patent system. In 1975 65% of new patents in America were for the inventions of Americans; 9% were for the work of Japanese inventors; 8.5% of Germans; and 7.5% British and French inventors combined. In the following decade America's share fell by ten percentage points, to less than 55%. West Germany's share rose a bit, Britain's dropped a bit, and the French stayed much the same. Japan's slice more than doubled to almost 19%. Japanese inventors now own more new patents in America than those from Britain, Germany and France.

Where does the Japanese technology go? The table, produced by matching patent classes with standard industrial classifications, offers some clues. By 1985 Japanese inventions accounted for 20% of new ceramics patents, 23% in primary metals, 26% in communications equipment, 30% in aircraft and their parts, and 33% in office-computing and accounting machines.

Admittedly, patents - and the earnings from them and their kin - are crude measures of how technologically advanced a country is. Take the payments, for example: as Japanese firms have invested abroad in the 1980s, they have used royalties and patent fees to repatriate profits from their plants overseas. That accounts for at least some of the move towards balance.

Patent figures, too, should be treated with caution. Some of the industry-sector figures (aircraft parts, for instance) are suspect, because it is hard to link industrial and patent classifications. Nevertheless, Japanese patents are cited more often than average in later patents - which is reckoned a good indicator of how useful an invention turns out to be.

Whatever the problems of measurement, the direction of change is clear. It is also clear that the change is fast. Buying technology was necessary to help Japan develop in the 1950s and 1960s. As the country's technological prowess grew, those imports became less important. In several areas - textiles, chemicals, iron and steel, motor vehicles - Japan already enjoys a surplus in royalty and fee payments. In short, it is becoming an exporter of technological ideas.

The Model T revisited

Do not lose perspective. America still has more scientists and engineers, spends more on research, and publishes more scientific papers than Britain, France, West Germany and Japan put together. Yet the flow of technology is changing direction - from Japan, instead of to it. There are two main reasons why.

Riches. After the second world war America dominated the world's human and capital resources. In the 1950s its command of technological resources began to reflect that fact. Since then the rest of the world has been catching up, first in Europe and later in Asia. Japan's growth has been the most startling. Japanese national income per head in 1968 was a mere 30% of America's; by 1988, it had grown to 120%.

Priorities. Japan has poured money and men into R&D. The number of scientists and engineers per 10,000 people has risen steadily since the early 1960s. In America it peaked in 1969. By 1986 Japan had a higher proportion of its population engaged in R&D than America did. Since the early 1970s Japan has also spent more of its national income on non-military R&D than America.

There is another thing. The distinction between two parts of manufacturing - design and production - is breaking down. For the second time in the twentieth century (the first was the arrival of mass-produced cars in the 1920s), the process of production calls for just as much technological expertise as does the design of a product. For instance, a dozen or so firms around the world have designed prototype four-megabit dynamic random-access memory chips, which will be the next generation of computer memories; the few that manage to perfect the production process will own a secret worth billions of dollars. Production technology is what Japanese companies are especially good at. Luckily for them, it counts for far more in the 1980s than it has done for half a century.

Overcoming the island spirit

Quick though it has been to acquire technological prowess, Japan is slower to send its new knowledge abroad. One simple reason for this is the complexity of the Japanese language. Relatively few westerners have mastered it - leaving much of Japanese science a distant secret. More than ten times as many Japanese scientists leave home to study than arrive in Japan from abroad. It does not help that Japan's big national universities, with reputations for research, are part of the civil service and do not admit foreigners as faculty members.

Much of Japan's liveliest work is done in corporate laboratories, where staff are hired immediately after graduation and linger until they retire. There is little of the mobility that marks many science careers in the West. Who - outside an inner circle of specialists - could name Japan's equivalent of the West's best pure-research centres, such as AT&T Bell Laboratories in new Jersey, or CERN, the particle-research centre near Geneva? Something similar is true of more down-to-earth commercial technologies. Although Japanese firms send staff abroad to pick up expertise in the research departments of foreign companies - around 100 are at Boeing in America, for example - few foreigners ever penetrate Japanese laboratories.

Japanese companies are undoubtedly reluctant to let their technological secrets fly the coop. Just as reluctantly, though, they are starting to change. Paradoxically, it is the fear of protectionism that has overcome their reluctance. In Asia, Japanese firms have been forced to swap technology for access to markets. The subsidiaries of Japanese companies and joint-venture partners from Bangkok to Taipei are using Japanese technology to make everything from steel to semiconductors, from cars to computers.

In America and Western Europe the picture is more subtle. To avoid import quotas and high tariffs, Japan's companies have invested far from home. Intended or not, the result is a significant transfer of technology. Take the car business. When Ford set up an American-based joint venture with Mazda, it subcontracted some transmission-manufacturing work to the Japanese company. Even though Mazda employees worked from the same blueprints, they churned out better parts. Both firms worked to the same engineering tolerances, but the accuracy of Mazda's machining was higher than specified.

A similar tale comes from Britain. Nissan's plant in Washington, near Newcastle, is shaking up the local car industry, not with new-fangled equipment brought over from Japan, but because Nissan has mastered the management of its manufacturing process.

Or consider the steel industry, where Japanese continuous-casting techniques are giving America's sluggish producers new ideas. (In continuous casting, metal is processed more as it would be on a production line, instead of being made in single ingots that have to be rolled.) National Steel is half-owned by a Japanese company; Kawasaki Steel has bought Armco; several other American steel companies have joint ventures with firms from Japan. As a result, Japan earns more than six times as much in technology fees and royalties in the iron and steel industry than it pays out.

So much for brawny businesses. In the brainy ones, Japanese firms are forced to be open with their technology for a different reason: the high costs of market entry. It can cost several hundred million dollars to set up an advanced chip-manufacturing plant, and not even the biggest Japanese electronics firm dares go it alone. Hitachi is selling Texas Instruments the secrets of how to stack semiconductors on a single silicon chip, not out of altruism, but because it needs Texas Instruments' expertise in other areas, such as software.

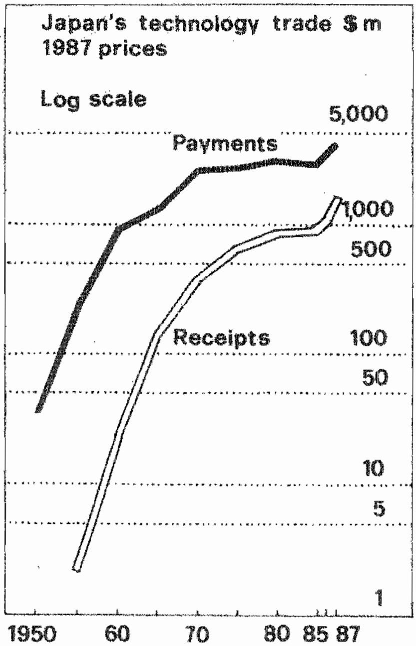
Remember Maudsley's lathe

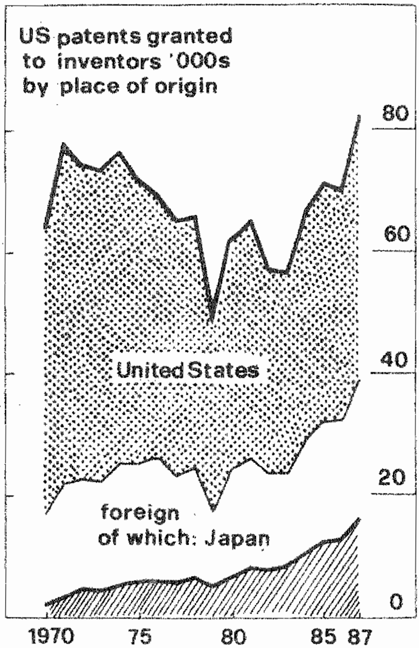
Such developments are all very well, a Japanophobe might say, but who did the basic research for these technologies in the first place?

True, America, and probably Western Europe too, are striding comfortably ahead of Japan across the fields of basic (i.e. pure) research. But it is not so long ago that Europeans levelled against America the complaints that Americans now aim at Japan. At the Great Exhibition of 1851 British industrialists strolling around the Crystal Palace in London were horrified at the quality of the latest American guns. Unfair, they said. The dastardly colonials were using a British idea (a new lathe designed by a Mr. Maudsley) to mill weapons with greater precision than the British. Then they had the cheek to sell Britons the fruits of their own basic research. Later, Britain made similar complaints about radar, penicillin, polyesters, computerised-tomography medical scanners - and much more.

In Japan, as in America in its time, basic research is proving a more delicate flower to cultivate than the hardier plants of industrial R&D. Japan produces less than 9% of the world's scientific literature compared with America's 35%. And the share of Japanese R&D spending devoted to basic research actually declined in the first half of the 1980s, from 15% to 13%.

Here, too, there are signs of change. The structure of university research in Japan remains largely unreformed: the curriculums still encourage people to learn by rote, not to think for themselves; professors are still promoted according to seniority rather than brains. But private companies are beginning to set up more imaginative research laboratories, where employees are encouraged to think beyond the next Walkman model. One such is Canon's laboratory at Atsugi, opened in 1985, which employs 300 people to do largely ruminative work on artificial intelligence, fibre-optic technology, new materials and electronics. It is structured more on (relatively) free-thinking American lines than as a rigid Japanese hierarchy.


Japan's technology trade $m
1987 prices
Log scale
5,000
Payments
1,000
500
Receipts
100
50
10
5
1
1950
60
70
80
85
87


US patents granted
to inventors '000s
by place of origin
80
60
40
20
0
United States
foreign
of which: Japan
1970
75
80
85
87

TABLE

Japanese-invented US patents

SIC category	share of total patents granted % 1975	1985
Food	8	11
Textiles	10	17
Chemicals & allied products	10	15
Petroleum	3	6
Rubber	10	18
Ceramics*	8	20
Primary metals	13	23
Fabricated metals	5	12
General machinery	7	15
Office-computing & accounting machines**	13	33
Electrical machinery	10	21
Communications equipment & electronic components	13	26
Motor vehicles	7	23
Aircraft & parts	10	30
Professional & scientific instruments	12	23
All fields	9	19

* Stone, clay, and glass products
** Includes computers

Source: National Science Foundation

APPENDIX XV

Promoting Progress through Science

by Guri Marchuk
President, Academy of Sciences of the USSR

To mark the seventieth anniversary of the October Revolution which led to the founding of the USSR, the following article by the leading scientist of the Soviet Union, Academician Marchuk, was submitted for publication within the pages of our journal. It represents a major review of the achievements of the scientists and technologists of the USSR, and a discussion of future directions and thrusts to be pursued in the coming decades.

Science has become a highly important human activity, exerting an ever-growing influence on all aspects of life in our modern society. Major scientific discoveries and achievements made during the last decades - first and foremost, the harnessing of nuclear energy, the breakthrough into outer space, the development of computers, lasers and new materials, and our understanding of the nature of living matter - have all had a profound impact on the development of production, on social consciousness, and finally on international politics.

Society's attitude to science is, in turn, altered by the development of production and social progress. In our country, cardinal changes in the status and role of science were associated with the October Socialist Revolution of 1917. The far-reaching transformation that occurred in all spheres of the country's social life endowed our science with new dimensions and new capabilities. Since those first years of Soviet government, the State has assumed full responsibility for the development of science, and the organization and backup of research, since science is regarded as an important means of building and consolidating our new, socialist society. The plan for the construction of socialism provided for closer ties between science and social production.

Reviewing the development of Soviet science since October 1917 we cannot help but recall the principle which was proclaimed in the very beginning of 1918 by V.I. Lenin: "From now on all the marvels of science and the gains of culture belong to the nation as a whole, and never again will man's genius be used for oppression and exploitation". This could not but attract Soviet scientists. Three months after the October Revolution the General Assembly of the Russian Academy of Sciences, the country's most authoritative scientific institution, adopted a Declaration to the effect: "The Academy expresses its constant readiness to turn to the requirements of the country and the State in order to tackle corresponding scientific and theoretical problems caused by the needs of national reconstruction, while remaining a centre of attraction and guidance for all the scientific forces of our country".

The Soviet State has always paid attention to the organization of new research institutes, including those engaged in fundamental studies, in order to develop the necessary conditions in which scientists could carry out creative work. It was essential to involve scientists in the solution of general problems vital to the country. One of the first such tasks was to develop the Plan of Electrification of Russia (GOELRO), which involved some 180 researchers and specialists.

During the decades since the October Revolution Soviet science has changed and strengthened with the country. The network of scientific institutions has been considerably expanded, qualified personnel produced, and an industrial base for science established. The Academy of Sciences has now become a major centre of fundamental research in the natural and social sciences, and a coordinator of science activities in the country. It possesses over 260 scientific institutions (against a single institute and several laboratories and museums in 1917), a Siberian Branch (with its own departments), Far-Eastern and Urals Branches, scientific centres in Leningrad and near Moscow, and six branches in the European part of the Russian Federation. The remaining fourteen Union republics have set up their own national academies of sciences. Furthermore, science is being developed in sectoral academies of agriculture, medical sciences and pedagogy, in research institutes of sectoral ministries and departments, and in higher educational establishments. The discoveries and achievements made by Soviet scientists during that period, and their contribution to world science, have gained wide recognition.

By what means and under the influence of what factors has such rapid growth of our country's material and spiritual culture been achieved? The answer is simple: scientific and technical progress has never been separated from social life; it blends organically with social progress. It is in this blend of scientific and technical progress with socialist construction in our country since October 1917 that the causes of the profound political and socio-economic transformation of Soviet society lie.

As far back as the 1920s and 1930s our science reached a high level in a number of areas of mathematics and mechanics, theoretical and experimental physics including optics, solid state physics and nuclear physics, chemical and biological sciences, and in geology and geophysics. Special attention was paid to the development of the humanities.

The level of research reached in the pre-war period enabled our country in the years following the Second World War to successfully solve such complex scientific and technical problems as the harnessing of the energy of the atomic nucleus, the conquering of space, and the development of computer-based control systems.

The strong scientific and technological potential created in our country over these seventy years has enabled our scientists and researchers to conduct research in virtually all the main areas of modern science and technology. Soviet science is very much a part of world science. With their discoveries and achievements Soviet scientists are making an increasing contribution to world scientific and technical progress.

New technologies and the future

An intensive economy implies, above all, the extensive application of fundamental scientific ideas that must be realised, through advanced technologies and original engineering solutions, and in new machines, equipment and instruments of the highest technical level. It is fundamental science which gives birth to original technologies and new principles of production.

This is particularly true of modern technologies. The end of the twentieth century is marked by a number of major discoveries that are determining rapid technological progress. These are, first of all, nuclear power engineering which has become an important area of power production; electronics, which embodies computers and automation; biology and genetics which created biotechnology as a whole new industry, and many others. On the eve of the next century there have emerged some two or three dozen technologies which are determining the character of scientific and technological progress.

Among them the pride of place arguably belongs to the laser which can be used for cutting and thermal processing of metals, for delivering information through optical fibre systems, the study of the atmosphere, in systems of diagnosis and the treatment of disease; and this is only a beginning.

Plasma technology is developing rapidly. Plasmatrons (generators of plasma) are becoming standard equipment in the processing of mineral raw materials, the creation of non-waste technologies, the production of materials with predetermined properties, and as an effective means of applying coatings. Plasma is used in large-scale industrial chemistry, the machining industry and metallurgy, and has a bright future before it.

A new vanguard technology is the work related to low temperatures and the use of the superconductivity effect to develop new generations of electrotechnical equipment. A 20 MW demonstration superconductor turbogenerator has already been built and another 300 MW generator is under construction. Of late, new opportunities have been created by the recently discovered high-temperature superconducting materials.

Another example of an advanced technology being developed by Soviet scientists is self-generating high-temperature synthesis, which creates a mixture of substances that burn throughout their whole volume from the point at which heat is first applied. Basically, the mixture contains components that release energy during the reaction. This 'solid flame' combustion makes it possible to produce rare refractory compounds.

The synthesis of diamonds from graphite has stimulated the development of high-pressure equipment and has inspired many scientists to develop their research in this area. It turns out that at pressures of several tens of thousands of atmospheres brittle materials such as molybdenum, tungsten and chromium become plastic, rather like soft steel or even copper. Thus a whole new area of materials science has emerged for future development. Equally, high-pressure chemistry now makes it possible to control chemical reactions, change their direction and velocity and conduct controlled syntheses of new compounds and materials with predetermined qualities: something of a technologist's dream.

We can cite a final example. As far back as 1826 a noted Russian metallurgist, P.G. Sovolevsky, suggested a radically new way of using metal powders. In our time this idea has given birth to a new industry - powder metallurgy - which takes advantage of the latest achievements in physics, chemistry, and engineering. It has become possible to preclude melting, casting and machining from the production process by replacing them with pressing and sintering.

These examples testify to the fact that fundamental science can change our familiar notions about the technical level of today's production and serve to outline technologies for the future.

Today, on average, it takes about ten years for a scientific discovery to become a widespread technology. That is why we have to already think in the categories that will be applicable to the end of this century. It is essential to imagine and understand the future of science a decade ahead primarily because it is the profound theoretical ideas that revolutionize society as a whole, its productive forces and S&T progress.

We soviet scientists strive to maintain contacts with scientists, specialists, research institutions, universities and firms of various countries, both developed and developing. Our main objective is cooperation in fundamental science, in the application of advanced technology and equipment, and in the solution of universal human problems.

All peoples on our planet share global problems that are becoming increasingly important. Indeed, today, societies are developing socially and economically at a rate and on a scale unknown to previous generations. In this connection such global issues as food, energy, environmental management, and health have emerged and grown more acute.

It is not secret that energy is becoming a key factor in the economic development of many countries. Science has paved the way to the solution of these problems. The harnessing of the energy of nuclear fission, particularly the transition to fast-neutron reactors, make up for the energy shortage. We could meet all our energy needs and solve the energy issue in a radical manner by realizing the controlled thermonuclear fusion of helium from heavy isotopes of hydrogen. Soviet scientists are working purposefully on the peaceful use of the energy of thermonuclear fusion energy, like scientists in a number of other countries. We need to pool their efforts in this area.

It will not be possible to ensure food supplies for the ever-growing population of the Earth without combining the talents of specialists in the different areas of agriculture, nutrition, health and economics. We need to reassess and reorientate the social and economic priorities of modern society, to pay close attention to the planning of agriculture and population growth. On the other hand science, primarily biotechnology, opens new possibilities for solving the food problem.

The constant growth of energy production, mad-made seas and reservoirs, cities inhabited by millions of people, vast areas of agricultural crops, the continuing transformation of natural vegetation - these are just some of the very visible features of the new habitat created by man. This habitat does not always fit into the extraordinarily complex, self-regulating mechanism of our global ecological system which is the fruit of an evolution that has taken place on a scale of millions of years on our planet. Deforestation, particularly in tropical regions, and the uncontrolled application of technological processes that produce toxic substances, are threatening our ozone layer. Imprudent application of chemicals and fertilizers is also seriously damaging the environment. Modern science is certainly capable of solving such environmental problems, but it is also obvious that the work requires efforts on an international scale; the pooling of financial, material and intellectual resources.

The Soviet Union, which is inhabited by one-seventeenth of the world's population, accounts for almost a third of world scientific production and a fifth of all technical inventions registered annually. This industry of ideas generates a growing interest in the world despite the still frequent attempts to play down its effectiveness and importance to commercial and non-commercial inter-state exchanges of the gains of the S&T revolution. To give but one example: in the last five years the Soviet Union sold to the USA more licences than the USA to the Soviet Union. Our country is directly interested in the development of cooperation. In the coming 15 years we shall have to create an economic potential equal to the one accumulated in the preceding seven decades, to increase productivity of labour almost 25 times and to double our national income.

Science is basically humanistic. However, achievements of modern science and technology can serve both social progress and destructive processes, including the elimination of mankind itself, depending on who possesses them and whose interests they serve. Science acquits itself in a fitting manner when it serves peace and is geared to the economic and cultural progress of society: to increasing the well-being of peoples. Such are the main principles of the USSR's science and technology policy.

(From Impact of Science on Society (published by UNESCO), Vol. 38, No.1, 1988.)

APPENDIX XVI

Science and Technology Policies in the Industrialization of a Developing Country – Korean Approaches

by Hyung Sup Choi

(Paper for the Background Documentation at the Task Force Meeting on the Role of Science and Technology in the Development of the South, South Commission, May 31, 1988, Geneva, Switzerland).

Introduction

Since World War II, many countries have made great efforts to industrialize their economies, reflecting the aspirations of their people. Although some failed, there were a few cases where special conditions prevailed for success or were made to prevail. Each success has been unique, and no all-purpose formula or guidelines seem to exist for others to emulate. Nevertheless, inquiry into the developmental process from the Korean point of view may be worthwhile.

The prospects for entering into industrialization today by developing countries are not so evident; nor can it be taken for granted that late-comers have the advantage. On the contrary, strenuous efforts are required to build up capacity for embarking upon industrialization. Elimination of the obstacles to industrialization is a long-term affair, which ideally should precede the industrialization process. If one were to try to accomplish the process all at once, the task would be formidable, or even impossible. Thus, a step-by-step approach should be taken to build the capacity for industrialization. In the process, one could capitalize on the advantages of being a "late-comer".

In any approach to industrialization in a developing country, great care must be taken in selecting the field to be developed and in deciding the extent of industrialization. These decisions must be based on a clear understanding of the country's potential and the constraints to which it is subjected. A country richly endowed with natural resources needed for industrialization may use a different approach from a country rich in human resources but possessing few natural resources.

To properly chart the path to industrialization requires consideration of numerous socio-political, cultural, and economic factors. The case of Korea will be discussed here as an example.

Korea opted for development of light, labour-intensive industries by absorbing the labour force from the primary sector. However, the demand for industrial products in the primary sector was too slight, so it was necessary to look outward for capital, markets, and technology. Korea, therefore, did not choose to develop industry first by pursuing import-substitution and then export-promotion policies; instead, the two were undertaken almost simultaneously, particularly when the first long range economic development plan went into effect. The apparent success of this bold approach can be attributed to several factors: 1) amenability to training and the absorptive capacity of the labour force in dealing with relatively sophisticated technologies, 2) close trade relations with the U.S.A. and Japan, both big markets, 3) full exploitation of the technical advantage of being a late-comer in industrialization, and 4) capacity to adapt to the international economic environment, which was actively supported by the government through creation of a favourable investment climate for foreigners [(1)].

The most conspicuous constraints for the rapid industrialization scheme were the deficiencies in the social overhead sectors. Because the infrastructure for industrial development was very poor, the government placed a great emphasis on quick and decisive action to build roads, ports, communications and other facilities essential to development including expanding facilities for technical education. About 50 percent of the total foreign capital induced was spent for these facilities, on top of over 70 percent of the total public loan funds from overseas.

The First Five Year Economic Development Plan (1962-1966) called for selective industrialization on one hand and the establishment of social infrastructures on the other, allowing the national economy to find a proper berth. Such industries as power, cement, fertilizer, and coal mining were among the targets selected by the government. Light industries, such as textile, plywood and consumer goods evolved largely from initiatives by private entrepreneurs who saw domestic captive markets for such products.

The Second Five Year Economic Development Plan (1967-1971) pushed forward the continued expansion of basic chemicals, petrochemicals, and iron and steel industries. Growth momentum was established through these sectors so that their dynamism could be felt within all Korean industries. These industries are highly capital intensive by nature and need a huge infrastructure which has to be supported by the government. They would not necessarily develop sufficient linkage effects directly, but they are essential to the foundation upon which the high linkage industries can be built.

One pressing problem in developing these leading industries was whether or not they could be operated at, or at least near, full capacity. The leverage was found to be extremely small, because the cost of capital for these industries, most of which originated abroad, was much higher than that required in advanced countries. This hard fact of life had much to do with the design of every industrial project.

The Third Five Year Economic Development Plan (1972-1976) more or less followed the same direction of industrialization. Greater economies of scale were needed along with development of agriculture and social services, to capitalize on the previous experience of advanced countries and of Korea itself and thus to maximize the advantages of the late-comers. This orientation necessitated the introduction of newer and higher level technologies on an order of magnitude never experienced. It was an irreversible decision and an answer to the issue of survival or extinction in an ever-stiffening international competition.

The technological development of a country usually starts with the importation of advanced foreign technology and proceeds, through development of domestic variants of this imported technology, to the final goal of technological self-reliance. However, little can be expected from imported technology in the absence of a capability to modify and improve it for domestic application. Therefore, to achieve viable results from the technology transfer, a corresponding effort must be made to assimilate and adapt imported technologies.

With these thoughts in mind, I will try to relate the role of technology in Korea's experience. I shall be giving more attention to the role of technology at the national level, not because I believe in a highly centralized system, but because of the impact it can have at the national level. The national government has a crucial role to play during various stages of industrialization and the choice of technologies to achieve those goals.

Macro-Micro Linkages for Science and Technology Development

In developing countries, technology has come to be viewed as one of the most important means of achieving national progress. The Korean government has planned intensive policies and strategies for the development of science and technology with many innovative supporting measures. Particular attention will be directed toward the use of high technology, for this was the path chosen by Korea to industrialize and to evolve an outward oriented economy [2]. While less sophisticated technology can surely serve the needs of some aspects of national development, Korea decided that the high technology path could afford it the most options in reaching development goals.

In this plan, Korea adopted a three-pronged approach, emphasizing a capability build-up, particularly manpower development at various levels, accelerated introduction of foreign advanced technologies, and stimulation of domestic R&D activities. To this end, the implementation plan was formulated in consideration of both institutional and legal factors.

Institutional Set-Up

The institutional framework of this approach was somewhat daring. It included the establishment of: 1) the Ministry of Science and Technology (MOST) in 1967 as the central policy making, planning, coordinating and promotional body in the government; 2) the Korea Institute of Science and Technology by a special law (KIST Assistant Act) in 1966 as an autonomous multidisciplinary industrial research institute; and 3) the Korea Advanced Institute of Science (KAIS) in 1971, in addition to existing universities and colleges, to be a mission-oriented post-graduate school. Finally, many vocational training institutes and high schools were established to meet the rapidly rising, almost explosive, demand for skilled workers and technicians.

In recognition of the need for an institution to bridge academia and industry, the traditional and the contemporary, and the domestic and the foreign, the concept of an intermediary agent was introduced. Accordingly, Korea first established an independent, multidisciplinary industrial research institute (KIST). The second step was the reinforcement of an information clearing house (KORSTIC) for industrial research. The third was the establishment of quality control and instrument calibration service centres as short-term measures in selected fields of industry. As a long term measure, the Korea Standard Research Institute (KSRI) was organized and reinforced to support industry.

The Korea Institute of Science and Technology (KIST) was created to bolster the industrial sector, particularly in those areas where the national economic development plan emphasized elimination of bottlenecks hindering further growth. This institute was established, through special legislation, as a contract research organization to make researchers aware of the marketing of technologies. In the realm of R&D, KIST was intended to make researchers problem-oriented and to impress the underwriters of such R&D with the importance of the implementation of the R&D results (3).

As industry grew, its technological requirements increased in level and diversity; as a result, laboratories, such as those in shipbuilding, petrochemicals, electronics, telecommunications, machinery and energy, which existed as integral parts of the institute, were no longer able to render sufficient technical support to industries growing at such a rapid rate. Independent research organizations specific to each industry and problem area became necessary. In order to address this formidable task, the government has made use of existing small laboratories at KIST as seeds and spun them off from the mother institute. Thus, they inherited not only accumulated experience but a workable management philosophy and a system all too often missing in a new organization.

In order to operate these institutes effectively, the Daeduk Science Town designed to house research organizations, public and private, as well as higher educational institutions, and thus formed an intellectual complex to contribute to the development of science and technology (4). It is expected that the Daeduk Science Town will develop as the cradle of Korea's burgeoning science and technology, eventually acting as the centre of national excellence.

Although there are several devices for inducing industries to perform R&D, the most essential one is to provide soft capital for technology development, due to industry's limited fund sources. In this respect, I will expand on Korean examples; the Korea Technology Advancement Corporation (K-TAC), Korea Technology Development Corporation (KTDC), Korea Development Investment Corporation (KDIC) and Korea Technology Finance Corporation (KTFC).

In 1974, K-TAC was organized to carry out the commercialization of R&D results of KIST. Currently, K-TAC has 8 subsidiary companies and it will add 6 more subsidiaries.

KTDC was established in 1981 as an autonomous public enterprise. To promote the R&D projects of industry which inherently involve substantial risks coupled with expected high returns, KTDC is willing to share both the risk of failure as well as the benefits of success. To this end, the corporation offers three different types of financial support; long-term loans, conditional loans and equity investments. The major activities of KTDC include support for all aspects of the introduction, improvement and adaptation of advanced technology, particularly semi-developed technology from abroad, the commercialization of R&D results, the development of new products and processes, and the support of plant engineering services. KTDC also provides special services in the area of technical advice, feasibility studies for R&D activities, technology transfer and management. Of the total funds approved during 1985, 37% were approved for 77 projects of the metal and machinery industry, 30% for 61 projects of the electric and electronics industry, and 33% for 50 projects of the chemical and other industries. The breakdown of projects showed that 86% of the total amount was provided for R&D activities and the commercialization of R&D results, 12% for technology imports and training, and 2% for the purchase of R&D equipment.

In another case, KDIC was incorporated in December of 1982 by the seven Seoul-based short-term finance companies in Korea. As a limited liability venture capital company, KDIC is designed to foster and strengthen the technology oriented small and medium industries in Korea through equity investment and/or equity-type investment. In addition to the provision of financial support, KDIC expects to support the management of its portfolio companies through its participation on the Board of Directors of these companies, as well as through the provision of business advisory services. Since the establishment of KDIC, 98 projects have been invested in. The investments include common stocks, preferred stocks as minority shareholders, convertible debentures and debentures with warrants. As of the end of June, 1986, the portfolio of KDIC by industrial classification was as follows; 32% for 38 electronics projects, 14.4% for 11 metal fabrication projects, 14.6% for 7 non-metallic mineral products projects; 13.2% for 18 food projects and 2.3% for 2 miscellaneous projects. KDIC purchases debentures and makes short-term loan for working capital only to its portfolio companies.

Lastly, KTFC was established in October of 1984 by the Korea Development Bank as a venture capital company. During 1985, KTFC appproved 71 projects of 58 firms and supplied funds in the form of equity investments, acquisition debentures, credit loans and conventional loans. The financial support during the year consisted of 24% to R&D activities, 45% to the initial commercialization of new technology, and 31% to improvements in the manufacturing process.

To meet the urgent need of industry for manpower trained to handle high level technology, the Korea Advanced Institute of Science (KAIS) and the Changwon Technicians College were established. KAIS provides post-graduate programmes in applied science and engineering in selected fields to educate a sufficient number of high calibre scientists and engineers to meet the emerging needs of Korean industry. This institution is trying to build a "centre of relevance" to the nation's economic development rather than merely creating a "centre of excellence" in academic pursuits. The Changwon Technicians College was established to guarantee a new social status based on professional pride in the skilled worker's career. This institution makes it possible for a skilled worker to become a master foreman through education in needed theoretical background and administrative skills, and later to become a manager or supervisor with the same social standing as a regular college graduate (6).

In the early 1970's, the growth of Korea's economy surpassed that of a semi-developed country and approached that of a highly industrialized nation. As a result, nurturing the potential of science and technology has become an immediate need. The trend at this stage of development is naturally to turn an eye to the development of basic science as well.

Research activities for basic sciences had to be supported on a national scale as the source for industrial technology. The support of basic research activities in universities and the establishment of the Korea Science and Engineering Foundation were a step forward in strengthening basic research fields. In addition, systematic and mutual cooperation between government, universities, industry and research institutes was recognized as a necessity.

While enterprises in industry are encouraged to finance their own R&D activities through the Law for the Promotion of Technology Development, those lacking in their own facilities and research personnel are induced to consign R&D tasks to "specialized research institutes" either entirely or on a cooperative basis. In addition to this way of promoting the cooperation between industry and academia, plans have been drawn up to establish an integrated research system to include basic, applied and development research.

The government also finances R&D activities jointly with private enterprises. The benefits of these joint research ventures naturally accrue to the enterprises involved, and have led to the creation of a number of laboratories financed jointly by private enterprises and the government.

Future government policy must focus on securing funds and research personnel for these institutions. As stated already, the lack of investment for R&D is one of the constraints to technology development, particularly in the private sector. Even enterprises with money for technology development may not know which organization might be best able to solve their technological problems. On the other hand, even if a research institute has developed a promising technology, it is not always an easy task to find the right client to use it. An intermediary to bridge academia and industry with sufficient funding capacity might offer a ready solution to these problems. It is suggested here that a specially equipped financial institution could act as such an intermediary. An industry, a research institution and a financial intermediary could form a tripartite system of cooperation to aid technology development. To create this tripartite system a financial institution which will play an effective intermediary function must be founded. Consequently, it will be imperative to strengthen the maximum utilization of existing institutions and to expedite the establishment of Technology Development Bank to ensure a smooth flow of money for R&D activities (7).

Legal Back-up

The Ministry of Science and Technology spear-headed the enactment of several very important laws for the development of science and technology. They include: the Science and Technology Advancement Law of 1967 which defines the basic commitment of the government to support science and technology and to provide policy leadership; the Law for the Promotion of Technology Development of 1972 to provide, among others, fiscal and financial incentives to private industries for technology development; the Engineering Services Promotion Law of 1973 to promote local engineering firms by assuring markets on one hand and performance standards on the other; the National Technical Qualification Law of 1973 which, through a system of examination and certification, promotes the enhancement of status for professionals in technical fields, particularly for those who practice skills; the Assistance Law for Designated Research Organizations of 1973 which provides incentives in legal, financial and fiscal terms for research institutes in specialized fields where the government and private industry place particular emphasis, such as shipbuilding, electronics, communication, mechanical and material engineering, and energy and related area; and the Law for the Korea Science and Engineering Foundation of 1976 which provides a legal basis for the establishment of the Foundation to act as the prime agent for strengthening research in basic and applied sciences, as well as in engineering, centered chiefly around universities, and to facilitate more rapid application of science and engineering to national needs.

Among these measures, I shall draw special attention to the Law for the Promotion of Technology Development of 1972. The law was passed to encourage the private sector to adapt and improve imported technology, and to develop domestic technology through the R&D activities of government subsidized laboratories. Subsequently, various tax and financial incentives have been provided. As a result, an ever-increasing number of enterprises have been allocating funds for R&D projects, and long-term low interest loans have been granted to those enterprises seeking to utilize newly developed technologies for commercial purposes. Encouraged by this government policy, many firms in the private sector are now showing a keen interest in establishing their own laboratories and equipping them with necessary facilities and qualified staff.

The government took a follow-up step in 1977 by amending the aforementioned law to 1) extend the tax and financial incentives to a wider range of industries, while making R&D activities mandatory for strategic industries; 2) take protective measures to create demand for products embodying newly developed domestic technologies; and 3) organize the Industrial Technologies Research Association to search for solutions to the problems facing small and medium enterprises and provide them with guidance on technology development.

Creation of a Favourable Science and Technology Climate

Science and technology development gains momentum when a suitable environment for its popularization is created. The creation and promotion of such an environment is a prerequisite for science and technology development, particularly in a country where social and economic patterns and customs are bound by tradition.

Korea has launched a movement for the popularization of science and technology as an integral part of its long-range science and technology development plan. The movement aims to motivate a universal desire for scientific innovation in every one in all aspects of their lives. It has been led by the Ministry of Science and Technology, the Korea Science Promotion Foundation, and the Saemaul Technical Service Corps in cooperation with concerned government agencies, industry, academic circles, and the mass-communication media. The basic goal of this movement is a reorientation of the public's attitudes. This movement is in no way conceived as the special province of scientists and engineers, although this group can provide key support and resources in view of its pertinent talent and knowledge. It is not intended to focus attention solely on major scientific or technological advances, but rather a vast number of small advances made by people in every segment of society. In all aspects of the movement, primary emphasis is given to rationality, creativity, and workability.

It is necessary to develop a rational and scientific way of thinking among the Korean people and to discard passive attitudes and practices. As the first objective of this movement, they must comprehend the importance of science and technology in economic development and must develop the habit of applying elementary technical knowledge to everyday life. The second objective of this movement is to encourage everyone to acquire technical skills. Third, this movement is targeted at the strategic development and expansion of the economy will require increasing scientific and technical abilities. Korea, like the highly industrialized countries of the world, must have all the resources of science and technology effectively at its command. This can only be possible if the spirit of every individual is oriented towards the basic values and methodologies of science and technology.

International Technical Cooperation

In the present context, we can see clearly the necessity of international cooperation of increasing global interdependence, in science and technology for the benefit of both developed and developing countries. As one cannot expect development of science and technology in closed or isolated societies, modern science strongly demands active international interchange and mutual cooperation. From this point of view, the efficient scientific and technological cooperation with all other nations is perhaps the essential factor that may determine whether or not a country can sustain development past a certain level. It is more so when a developing country depends inevitably on the transfer of the science and technology.

The term, "technical cooperation", is often used when discussing the problems of developing countries, but its origin can be linked to the term, "economic and technical aid", that was used in the 1940s. In the 1960s, the term, "economic and technical aid" was changed to "technical cooperation" as the donor, who offered the aid, and the recipient, who received it, took more seriously the mutual cooperation and the supplemental nature of this cooperation in order to increase the effectiveness of technical aid.

From the early 1970s, two new dimensions in technical cooperation evolved: i) the country programme approach that was the heart of the new movement by the UNDP, being influenced by Jackson's report, and ii) mutual technical cooperation among developing countries (TCDC) which is accomplished through the new international economic order that was decided in the Sixth Special Session of the UN General Assembly.

The basic concept of the country programme approach was to orient the conventional, segmented and fragmental technical cooperation activities into recipient-sided cooperation which are more suited to the need of the recipient's country based on its long-term development plan. The establishment of a long range plan supported by the UNDP with links to individual nations' long term development plans enables developing countries to adapt technical cooperation to their needs. The truth is that there is strong desire to apply the country programme approach together with bilateral and multilateral technical cooperation to a large majority of developing countries. Recently in the international society, the basic spirit of mutual technical cooperation among developing countries, which is becoming more prominent, seeks to cast off the methods of technical cooperation that produced the former master-servant relationship by pursuing actions of the modern developing countries using the massive human and natural resources which they possess. All participants, without discriminating donor nations from recipients, are perceived with the dual roles of donor and recipient.

The process of technology-paced industrial development starts with the importation of foreign technology and proceeds to a final goal of technological self-reliance. The process needs a catalyst of technological cooperation to succeed.

The current international cooperation in technology has been more in form than in substance. The technological gap between advanced and less developed countries is too great and the understanding of mutual conditions and interests too meagre, resulting in technologies offered by donor countries proving to be inadequate or difficult to adapt to the capacities of recipient countries. Therefore, there is a need to design a new mechanism to render international technical cooperation, which is flexible and effective.

Furthermore, a review of the previous features of international cooperations in technology and economic development, indicates the following points to be considered for increasing the efficiency and effectiveness in utilizing technical aids from advanced countries.

1) The appropriateness of transferred technologies must be determined to suit specific conditions and basic needs of less developed countries (LDCs) under the "Country Programme" concept.
2) It is recommended that techno-economic feasibility study must be performed prior to the formulation of projects, by the mobilization of "in-country talents" supplemented by foreign experts.
3) Utilizing the absorbed and digested technology of the newly industrialized countries (NICs) with the accumulated experience of adaptation in their economic development might provide a helpful guide for the technology development of LDCs, minimizing the trials and errors.
4) Evaluation of project proposal and implementation plan offered by the donor countries should be done by the expert of third country which is not related to the supplier of equipments and services.

Under these circumstances, a tripartite cooperation system may be desirable to assist the LDCs to develop and adapt more effectively the technology needed for their economic development. The so-called "Tripartite Technical Cooperation" scheme consisting of the NICs, jointly with the advanced countries or relevant international organizations is believed to have a special merit for the technology development of LDCs to fill the gap between the recipient countries' capability of implementing the recommended development strategy and the donor countries' understanding of complex particular situations of the LDCs.

In this respect the Asian and Pacific Centre for Transfer of Technology (APCTT) of the UN-ESCAP has already initiated a few pioneering projects, such as the Technology Atlas project and the Technical Human Resources Development project. In these projects, APCTT and Korea together constitute the catalytic party for meaningful technical cooperation between the two conventional parties – the donor and the recipient – and thus resulting in a tripartite cooperation.

Guidelines for Future Development

Once a country has reached the take-off stage in its development, some kind of boost may be necessary to ensure that the momentum of development is maintained; however, it is equally imperative that the industrialization process be put back on a normal track as soon as possible. To this end, a unique industrial structure and direction for the industrialization process must be established on the basis of the actual conditions in a given country.

In view of the Koreas's conditions, it would seem that what is needed is not the blind pursuit of ever-increasing scale; instead, the industrial structure should stress the manufacture of products with a high added value stemming from the asset of a high quality labour force combined with a sparing use of natural resources and energy. In this way, it will be possible to develop strategically specialized industries which emphasize technology and brain-power. If kept small in scale, they may not be bogged down by huge infrastructures which in turn require immense capital investments. Thus, it should be possible to achieve stable prosperity while avoiding unnecessary competition in the international division of labour.

In making this argument, it is not my intention to minimize the significance of large-scale industries. Rather, the development of these basic industries should be pursued with some restraint in order to free resources necessary to support the minimum demands of the more specialized industries which produce high value-added products. After all, ensuring a stable supply of the major raw materials and semi-processed products is a prerequisite for a final product which will successfully compete in international markets. In other words, basic industries must be developed as a foundation for industrialization, but the scale of these industries has to be determined in terms of what is appropriate at a given stage and in terms of the goals being pursued. Moreover, it is necessary to achieve a balance between quantitative and qualitative production as well as between facilities and technology.

It is, therefore, quite evident that, in a country like Korea with its limited territory, scarce natural resources and high population density, it is skill and brainpower which provide the base for national development. Consequently, while we are laboring to foster the needed manpower, we must also search for a technological development strategy which will employ this superior manpower within an industrial structure which makes the most of technology and brainpower. To place emphasis exclusively on those industries which require a huge infrastructure would mean prevailing instability with the concomitant loss of the opportunity to join the ranks of the developed countries. Taking this perspective, it is clear that our efforts must be bent toward achieving that "small but advanced" type of development which is exemplified by such European countries as Switzerland, Belgium, the Netherlands, Denmark and Sweden.

To realize the technology-intensive industrial structure, it is necessary to 1) foster the development of strategically specialized industries; 2) optimize the social and industrial system; and 3) promote the quest for a high technology society [8]. As was pointed out earlier, strategically specialized industries will have to be characterized by a propensity to economize resources and create employment opportunities while requiring minimal capital investment and producing little environmental pollution. Furthermore, a country has to minimize its spending on social overhead to compete successfully with the fully industrialized nations and resource-rich countries. For this reason, optimization of the social and industrial systems is a very important strategic goal.

Looking at the situation from another angle, science and technology, especially technology based on science developed during the second half of this century, has exerted a great global impact on mankind, resulting in the apex of the so-called "industrialized society". This impact has become greater and greater in recent years, leading to a societal transition. Such a societal change due to recent, rapid technological progress will transform our present society into a post-industrial or information society.

As can be easily observed, advanced countries are now tending to switch their industry-oriented development strategies to information-oriented ones. Developing countries are bound to be affected by this trend, and thus are required to turn their eyes toward a new information-oriented development strategy in the foreseeable future. In order to meet this demand, they have to seek and adopt the basic concept of an information-oriented society. The first step towards this new concept is to establish a system for the settlement of an information-oriented society. Since the most pressing demands in this regard will be effective utilization of computer systems, we have to become prepared to face the upcoming challenges.

Concluding Remarks

Now, let me make a few closing remarks. First, the notion that industrialization in a developing country does not create enough employment to make it worthwhile, has limited validity. In the case of Korea, industry has provided at least one-third of all jobs created since 1962. Second, the idea that developing countries do not require high technology if they set their targets towards agriculture rather than industry is not completely valid either, especially when there is limited arable land, which must support a large population. Agriculture does require a considerable array of what might be called high technology, as in the development of high yield crops suitable for particular ecological and environmental conditions. Third, the argument that developing countries do not require domestic R&D, but require injections of technology from developed countries, is not sound. Domestic R&D is a prerequisite in enhancing the technological literacy necessary to make it possible to take advantage of foreign technologies. That is, industrialization in a developing country with high selectivity in terms of sector, size, and degree of capital and technological intensities can bring about many essential improvements. The problems that need to be solved in a developing economy often require high technology, which can set development in motion to overcome insurmountable obstacles. Fourth, the developing countries have to become prepared to face the upcoming challenges in an age of technological change. It is asserted that the future society is one in which science and technology will determine the direction of socio-economic changes. The speed of such a societal change is accelerating and the area of impact is broadening, while the nature of change is even more sophisticated. Lastly, but probably most importantly, developing countries should not be swayed by the prevalent notion that the generation of technology in developing countries is not economically sound, if not impossible. On the contrary, I believe that there is a vast scope, and an absolute need in developing countries for the generation of technologies by those countries themselves or perhaps in collaboration with developed countries. To accomplish this end requires highly qualified people more than anything else; they are the only ones who can change the methods and the milieu.

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Nine years after the end of the Korean war, capitalism had done little for South Korea. In 1962 the country's GNP per head was $100. Its exports, mostly of primary commodities (such as raw silk and animal products), totalled $43 m. Growth in income per head had averaged less than 1% a year since the war.

Domestic saving s were negligible. The current account of the balance of payments was in deficit, as throughout the country's 13-year history. And population growth of 3% a year - worrying for a fairly densely peopled country in the southern half of a mountainous peninsula - meant that the economy would have to grow by some 5% a year to furnish jobs for the newcomers.

The picture today is staggeringly different. South Korea is a thriving industrial economy. Farming's share of gross national product (GNP) fell from 431/2 % in 1963 to 15% in 1984; the share of manufacturing has risen from 10% to 31%. The country has turned from being an exporter of commodities to a net importer of them. As a result, it depends more than ever on trade: its exports more than doubled as a proportion of GNP from 14 1/2% in 1963-73 to 391/2% in 1981-87. The country has tamed its foreign debt: its (gross) debt-to-GNP ratio, after rising from 28% in 1970 to 521/2% in 1980, fell to 22% last year. South Korea could become a net creditor in 1989. ...

In the course of these changes, the country's economy grew at an an average rate of 81/2% a year between 1962 and 1985. Its GNP per head is now $2,800 - more than Brazil's, and not far behind Portugal's. ... In each of the past three years, Korea's current account has shown a surplus. Last year's was $14 billion. These days the government's biggest economic problem is to decide what to do about these accumulating external surpluses. ...

This rags-to-riches story is a rarity to begin with - but it has another unusual aspect. The country's growth has not caused extreme disparities between rich and poor - in contrast with many other developing countries, successful or not. The World Bank reckons that the poorest two-fifths of the people receive 17% of the country's income, the richest fifth 45%.

That compares favourably with Latin America, say. In Mexico, the poorest two-fifths receive 10%, and the richest fifth 58%; in Brazil, the figures are 7% and 67%. On this measure, Korea's income is also more equally spread than that of Thailand or Hongkong.

The recipe for economic success seems to have had three ingredients: few natural resources, but great human ones; a relentlessly "outward-orientated" development policy; and far-reaching, yet flexible, government intervention in the economy.

When the division of the peninsula was fixed again after the Korean war in 1953, the north got the natural resources, the south got the people - 42m today, double the number in North Korea. The South Koreans are a well-educated lot. In 1960, 27% of children of secondary-school age were enrolled at school. That compared with 64% in industrial countries. By 1983, enrolment in rich countries had grown to 85%. In Korea, it had shot up to 89%. As a result, almost everybody can read and write. This is partly a matter of cultural inheritance, but not entirely. It also reflects a deliberate policy of spending heavily on education.

Another virtue, by government command, was industrial peace. Although unions are legal in Korea, they were vigorously discouraged until 1987, and until then strikes were largely unheard of. Opposition parties are still calling for the repeal of many repressive laws.

Koreans also have to put up with longer working hours than their counterparts in almost any other industrial economy. In the 1960s, Korean manufacturing workers put in ten hours a week more than their Japanese or Mexican equivalents, and almost 15 more than Americans. ...

Believers in free markets wince at many aspects of Korea's economic policy. The government has long been highly interventionist. Over the years, for example, it has relied on credit rationing, a manipulated exchange rate, rigid control of the financial sector and a fully-fledged industrial policy. In one way or another, the government has controlled much of the economy. ...

Outward-orientated Korea succeeded where import-substituting Latin America had failed. There, "protection was too comprehensive", say Messrs. Dornbusch and Park, "and too little attention was paid to the possibility of exporting manufactures".

The other big difference between Korea and Latin America is inflation - the realm of macroeconomic policy. Unlike the governments of Brazil, Mexico and Argentina, Korea's avoided big budget deficits. As a result, the public sector's foreign borrowing stayed small - and the money, in any case, was used mainly to pay for capital investment (which generates income for debt service). ...

Korea's economy in the late 1980s is far more startling than ever. Fears that Korea would not be able to pay its debts have faded as the country has racked up ever bigger current-account surpluses. Liberalisation has continued.

(Taken from *The Economist*, 4 March 1989, pp. 101-102).

APPENDIX XVII

"Beyond the Green Revolution"
by Nadir Azam-Ali

(*The Herald*, January 1989)

The green revolution strategies of the last quarter century have almost run their course. Pakistan now has the opportunity to participate in a second green revolution - one that can harness the wealth of climatic diversity and rich source of indigenous plant species available here.

Directly or indirectly, agriculture supports more than 70 percent of Pakistan's population. It accounts for about 75 percent of export earnings and employs more than 50 percent of the nation's workforce. It is the largest single sector of the economy. However, the development of indigenous agricultural science has largely been ignored by all governments throughout the four decades since independence. This neglect has meant that agriculture remains the "Cinderella" of Pakistan's industries. As we enter a new year and a new era in the political life of the country the future of agriculture deserves more than platitudes from the nation's decision-makers and more than lip-service from the thinking public.

It is particularly relevant to consider the future role of agriculture as the green revolution strategies of the last quarter of a century have almost run their course. For many of the farmers who initially gained from it, there are few new technologies that the green revolution can offer to substantially increase their yields. More importantly, for many subsistence farmers cultivating rain-fed lands it may as well never have existed as their crops and circumstances were never included in its philosophy. We need to reconsider which crops we grow and re-examine the potentials of ancient species, such as millets, which have been successfully grown for centuries without, and often despite, the efforts of modern science.

Pakistan now has the opportunity to participate in a second green revolution, not one that is entirely dependent on imported and often inappropriate, technologies, but one that can harness the wealth of climatic diversity and rich source of indigenous plant species available within its frontiers. The new spirit of co-operation generated by the recent SAARC summit, affords, at least in principle, an opportunity to place agriculture in a regional context. The vague statements about integrating agriculture and formulating a collective response to natural disasters need to be sharpened into an action plan for agricultural research and environmental conservation based on many shared experiences and perceptions. This could be a unique example of South-South collaboration, but first we need to examine our preconceptions about agriculture.

There exists a dichotomy in the minds of the educated urban middle-class. Most city dwellers have a cosy stereotype of rural life: the tranquility of the countryside provides a welcome escape from the traumas of the city; country folk live peaceful lives in picturesque villages interspersed by fields of golden corn; farmers are "sons of the soil," mostly honest worthy types if a little simple and dull.

However, although it may be visually appealing, their work remains unappetising to urban man. Though it may be metaphorically acceptable to get "one's hands dirty" in the cut-and-thrust of business deals, to get one's hands physically dirty is unacceptable to the upwardly mobile. This notion of agriculture as physically arduous and intellectually unrewarding extends from practice into theory. Agriculture is a "craft" rather than a "science," and is prone to large uncertainties as crop yields are perpetually at the mercy of unpredictable elements such as sun, rain and wind which vary from year to year. How then, it is argued, can its study be a rigorous and numerate science requiring agile minds? Convincing the government and public of this is the dilemma that faces agricultural scientists throughout the world. The consequences of this argument affect us all; its solution is a subject that we ignore at our peril. Man's activities mean that the future is not what it used to be.

The history of modern agriculture is a brief one. About a century ago, chemists found that the derivatives of nitrogen, phosphorus and potassium could dramatically enhance the growth and final seed yields of crop plants. However, it wasn't until the 1920s that the industrial extraction of nitrogen from air made possible the large-scale manufacture of nitrogenous fertilisers by chemical means. At about the same time, plant breeders began to select high-yielding cultivars of species, such as wheat and barley, and in the years that followed the potential yields of crops increased dramatically. However, crop plants remained highly vulnerable to the ravages of diseases and predation by pests.

The 1930s and 1940s saw the rapid development of synthetic chemicals which lead to the production of fungicides, herbicides and pesticides, such as DDT. By the 1960s, improvements in genetic research, allied with the development of agro-chemicals and fertilisers, formed the basis of the so-called "green revolution" that transofrmed agriculture throughout the developed world and in selected regions and crops of the developing world.

The green revolution technology involved a package of high-yielding varieties, guaranteed irrigation, costly inputs of fertilisers and effective control of pests and diseases. Because the new varieties were generally insensitive to day-length, they could be grown at any time of year. So, where previously only one crop was grown, the same land could now support two or even three crops annually. The green revolution technology offered enormous opportunities and was rapidly adopted by enterprising farmers with the financial means to buy costly inputs and with ready access to irrigation. For certain crops, the new technology was almost universally adopted. For example, by 1983 almost 90 percent of the wheat grown in Pakistan came from the new semi-dwarf varieties. Thus, for crops such as wheat, rice and to some extent maize, average yeilds more than doubled between the mid-1960s and the mid-1980s.

However, as with all revolutions, there were those who failed to benefit from the new regime. These were predominantly poorer farmers who cultivated thin, impoverished soils which were entirely dependent on unpredictable and infrequent rainfall. These farmers rarely had enough cash or credit to purchase the expensive inputs required by the new technology and successive governments failed to support them as they considered their marginal, rain-fed lands to be too risky for agricultural development.

Without irrigation, the new varieties often faild completely and the only crops that could be grown in these regions were hardy drought-tolerant cereals, such as millet and sorghum, or leguminous pulses such as pigeon pea. The green revolution did little to produce high-yielding varieties of these less valuable species so that these crops were predominantly consumed by the farmer and his family for their subsistence and were unable to provide cash for other material benefits.

Thus, in a very real sense, the green revolution meant that wihtin each country the rich got richer and the poor got poorer. Pakistan provides a vivid example of the disproportionate effects of the new technology. In this country, of the 20 million hectares under cultivation, 25 percent is rain-fed. In terms of each province, 15 percent of the cultivated area of Punjab is purely dependent on rains, for Sind the figure is 44 percent and for both Baluchistan and NWFP the comparable figure is 60 percent. It is these areas, and the nutrition and welfare of their inhabitants, that agricultural research and government policies have ignored.

The future problems of these areas are likely to get worse rather than better as their further impoverishment has a global dimension. Since modern man began the large-scale burning of fossil fuels and the indiscriminate destruction of forests, the atmosphere of the earth has been gradually hearing up through a process known as the "greenhouse effect." This is because carbon dioxide levels in the atmosphere are increasing as a direct result of man's activities. Carbon dioxide is lieterally the "stuff of life" as it is absorved by plants and converted, via photosynthesis, into carbon-based products such as leaves and grain. However, it is the indirect effects of an increase in global carbon dioxide, accompanied by the depletion of the ozone layer, through the industrial use of cholorfluorocarbons (chemicals used in aerosols and refrigerants) that are so alarming.

We are only too aware of what a nuclear explosion would do to life on earth, and events such as Chernobyl, have shaken us out of our apathy into doing something about nuclear proliferation. The greenhouse effect is potentially as dangerous for vast areas of the globe, but because it is a slow, lingering death we remain unconvinced of its consequences. Gradually carbon dioxide is forming a planetary layer which traps solar heat and prevents it from being reflected back from the earth's surface. The net result is an increase in the earth's temperature, disturbance of finely-balanced climatic systems and a melting of ice which is currently locked up at the North and South poles. The exact environmental consequences of this are still uncertain but it is generally accepted that mean sea levels will rise, with devestating implications for regions such as Bangladesh and particularly for the Maldives, which are only about one metre above mean sea level.

For Pakistan, the scenario includes an increase in the rate of desertification as average temperatures increase and as rainfall becomes less predictable in amount, duration and frequency. Areas previously thought of as able to sustain high-input agriculture may become marginal for crops such as wheat, and currently marginal lands may become unproductive altogether. There will be greater variations in weather patterns within each year and between years and this means that we can no longer rely on intuition as our guide when making decisions of agricultural policy.

So, what is to be done? Firstly, if you look at the agro-meteorological map of the world you will find that Pakistan is almost absent from it. Compared to, say, India, weather stations are few and far between and daily records of weather variables are often limited to rainfall and temperature. Weather information has largely been collected for military, not agricultural, purposes. This omission would be more acceptable if Pakistan was more or less uniform in topography and climate. However, it is geographically diverse and includes local climates that range from arid deserts to mountain systems.

To define the regions that are most suited to the growth of different crops we need to first accurately record and define local climates using modern weather stations. A network of these stations needs to be connected by a computer-based system of data collecion so that weather patterns can be rapidly analysed and included in global records.

We require accurate models of crop/weather relations so that we can provide recommendations, say for the Northern Areas, about which crops whould be grown where, when and for how long. Such predictive models can be devised, using local weather records allied with factors such as soil type, aspect, slope and altitude. Again, weather information, such as rainfall, temperature and windspeec, can be combined with local information about soil type and depth to calculate exactly how much water is available to crops growing in rainfed areas without supplementary irrigation. This information would allow us to determine the optimum planting densities at which to sow particular crops to ensure that they do not run out of water before they yiled grain. In the past, these planting densities were determined by a long process of trial-and-error. There is no longer sufficient time available to rely on these traditional approaches for future agricultural development.

Secondly, we need to improve the yields of crops that have already benefited from the green revolution. Despite the increases in yields obtained during the past twenty years, the average wheat yield in this country remains less than that in India and only about 25 percnet that of Mexico. Similarly, the average yield of sugarcane remains less than India's yield and is only about 47 percent of the average achieved in Egypt. A country as rich s Pakistan has no excuse for these fingures. Agriculture is a serious subject and should no longer remain a hobby for feudal barons or retired brigadiers. Where high input systems exist, their efficiency in terms of inputs and yeilds needs to be substantially improved, through specific research and extension. Again, more weather information is needed to provide accurate date about when to spray crops to provide optimal protection againsts pests and diseases.

Thirdly, mankind obtains more than 90 percent of its food from only 17 species, which include cereals, such as wheat, rice, maize, millet and sorghum; legumes such as groundnut and soyabean; root crops such as casava and tree crops such as bananas and coconuts. The hardier drought-resiseant species, such as millet and sorghum, will increase in importance as climates become hotter and drier. Pulses, which are a rich, cheap source of vegetable protein, will become particularly important as animal protein becomes scarcer and more expensive. A second green revolution is needed to imporve the yields and quality of these crops: a revolution that has already been achieved for wheat and rice. The new package will, by necessity, be different in philosophy from its predecessor and involve lower, more accurate inputs of fertilisers, irrigation and plant protection measures. The research needed to achieve these objectives will be more difficult than before but its success will provide a more sustainable system of agriculture for future generations.

Finally, we need to explore the vast potential of indigenous plant species which have been completely ignored by the green revolution. Species are disappearing at an alarming rate as human food needs become concentrated on a narrower genetic base. There remain about 300 species that are cultivated by man. Many of these are rich in essential nutrients, grow in regions which are too hot or too dry for modern crops or produce compounds which can be used for medicinal or industrial purposes.

In the past, these species were ignored because the agricultural development of the Third World was based on the colonial appetite for cash crops rather than on food crops for local consumption. Many of these old crops have survived generations of neglect or active discouragement by agricultural science and they are often still grown in traditional systems. Farmers usually have a very good reason for growing them and often they and their families prefer these crops to the more recently introduced alternatives. We need to re-examine these species crops and assess their potential for cultivation on a larger scale, particularly in areas which are marginal for modern crops.

Because of its wide diversity of climates and soils, Pakistan is an ideal country in which to explore the potentials of these crops. The identification of useful species, the optimal agronomic practices to maximise their productivity and programmes of plant breeding to select desirable genotypes are all urgent tasks. They cannot be undertaken piecemeal but must be done through integrated scientific effort supported by a receptive agricultural industry. To succeed, the future agricultural development of Pakistan will need highly motivated, intelligent and imaginative scientists and strategists who can integrate their research efforts with those of the international scientific community.

(The author is a lecturer and researcher in tropical agronomy with the Tropical Crops Research Unit at the University of Nottingham, U.K.)

APPENDIX XVIII

An Open Letter to the Prime Minister of Pakistan From Azim Kidwai

(Dawn Overseas Weekly (Karachi), 9 February 1989)

"Dear Prime Minister,

"I am a student of science and not a political animal; nevertheless, in the heady days these past few weeks, the political events erupting as loud as a whistling kettle on the boil, kept convulsing and putting science in the backyard of the mind. But science is my first love, and now no longer imprisoned by the pace of political events, I can stray back to my straight and narrow path, but with a difference. I can see some light at the end of the tunnel.

"Before coming to the main subject, however, let me congratulate you with all sincerity on your meteoric rise to power and to the high office of Chief Executive of the country at such a young age. The phenomenon is a surprise for millions, including some of the fossils like us who are almost twice your age, and I wish the best of luck to you in the challenging tasks ahead.

"Writing this piece at this moment of time came as an imperative to me. For I see you in the crystal ball at the helm of affairs, ushering us into the 21st century. And, that dream - entering the 21st century - for us, the students of science in Pakistan, has been almost a nightmare, since science could not avoid the axe during the last decade. It was in very low priority, and we could see predicaments in the sky, as if slipping down into the 'fourth world'.

"Now, as you know, there were no VCRs, no type-writer size personal computers, no genetically engineered 'human' insulin only 12 years back; but the next 12 years are going to see an advance ten times greater.

"It is going to be an age of insight, an age of instant information with an unprecedented computing power and an era of understanding how things work at the sub-atomic level and in the unbounded cosmos at macro-level.

"Against such a futuristic fantastic perspective just around the corner, science has been made to remain like a Cinderella in Pakistan, a fact which you may be well aware of. But what may not have come to your knowledge is the extent to which the scientific roof has caved in.

"So, first of all the state of science in Pakistan. Later in this piece, I will be begging of you to look into some of the remedial measures that could perhaps salvage the position.

* The number of Ph.Ds in science being produced in Pakistan is about 20 per year (counting in all the 20 universities) against a figure of over 3,000 in India and 5,000 in the U.K.

* Pakistan was graded as third in science and technology among the 7 leading Muslim countries in the period 1971-76. It was downgraded to the sixth position in 1985.

* The country has about 1,900 scientists/engineers per million population as against 4,100 in Iran and 6,900 in Turkey.

* According to UNESCO criteria, scientists in R&D (research and development) activity in Pakistan should be over 25,000 on the basis of population and per capita income. The figure is only 6,500.

* In 1985, there were 64 in R&D manpower per million population in Pakistan, while there were 352 per million population in Turkey, 957 in Korea and 4,750 in Japan.

* Pakistan is spending only about 0.2% (one-fifth of one percent) of GNP on R&D in science, while the average for developing countries is around half a percent. Various U.N. forums have recommended at least 1% of the GNP for developing countries for it. India has touched that figure.

"The developed nations spend over 2% of their much larger GNPs under that head (our GNP is only 31 billion dollars, India's 204 billion dollars, Japan's 1227 billion dollars).

The gap between Pakistan and the developed countries is widening instead of getting narrowed mainly because of sidmally low spendings in this sector.

* A "Science Policy" was announced in 1984 and was approved of by the Cabinet, but its king-pin clause has not been implemented. The policy is, therefore, iwth out any direction and without the necessary clout.

"The fountain-head of the Science Policy is supposed to be a high-powered National Commission for Science and Technology (NCST), headed by the Chief Executive of the country. It is described in the Policy "as the apex decision-making and coordinating agency for science and technology in the nation".

"It might come as a surprise to you that the Commission has not held even its first meeting in the last 5 years, though an imperative clause is there in the Policy that it will meet at least once every 6 months.

"It is said that the Chief Executives did not find time to chair it even once (the Ministry of Science also perhaps did not show enough dynamism).

"These seven points should turn out to be a good index of the state of science in Pakistan in the global context, as also in the context of the developing countries, the last point being most indicative of the fact that the government was not concerned in promoting science in the country, profuse lip-service notwithstanding.

"Counting the cost of neglect of science is not necessary: you being such a wise person, enlighted, can, I am sure, hear a grim sound much before the tramp of ominous boots is audible.

"To salvage the position, it is, therefore, suggested that

1. the Prime Minister may kindly give consideration to the possibility of taking over the science portfolio with a view to imparting prestige to science in the mind of the common man and to provide an impetus to its promotion, as did Pundit Jawaharlal Nehru in India after Independence. and kept the portfolio to himself until the end;
2. the meeting of the highpowered National Commission for Science and Technology that has been kept in abeyance for almost 5 years, be called as soon as possible;
3. the funding towards R&D in science be immediately raised to 0.5% of the GNP and a timetable to raise the figure to 1% within three years be announced;
4. each university be required to produce at least 20 Ph.Ds in science every year and resources for Ph.D programmes be reinforced wherever of substandard level. Thereafter, the heads of university departments who cannot meet this objective should be transferred from the R&D sector to administrative or purely teaching jobs in colleges;
5. sending 400 to 500 persons for Ph.D programmes abroad every eyar, involving billions of rupees, be discontinued. Instead, the same amount could be diverted to the universities for building Ph.D programmes in the emerging sciences and technologies. Wherever necessary Pakistanis with a proven ability (with at least ten research publications in international journals of repute) might be invited to come for this programme at their world market-price. In case Pakistani scientists of proven ability are not available in a certain field, foreigners with with similar qualifications may be contracted for 2 to 3 years.

   Ph.Ds produced this way will have better acumen to work on indigenous problems;
6. at least two institutions on the pattern of M.I.T. in the USA or the Korean Institute of Scienc and Technology (KIST) be set up (of course on a smaller scale to begin with), one in the northern region and the other in the southern region of Pakistan, to develop the nuclei of education and research of an international standard. India has 5 such I.I.Ts (Indian Institutes of Technology), acting as pivots in India's advance in science and technology;
7. the educational standards of science in the colleges be raised by equipping their laboratories properly and recruiting a teaching staff with first class careers;
8. scientific literacy in the country be raised through the mass media, particularly the electronic media, the government as well taking other supportive measure in that direction.

   Science centres, science clubs, must be engineered in the cities, a 'science-caravan' for each district rigged up to visit the villages of the district periodically. The 'caravan' could be quipped with interesting models and experiments as also with scientific films, particularly on agriculture, for village folks;

9. each primary school have a graduate in science as science teacher in order to develop a sense of enquiry in young minds;

10. research and de elopment effort in the energy sector, being very meagre requires that nuclear power plants be built on a war-like footing to close the energy gap in the dying years of the century.

"In the end, Ms. Prime Minister, I can assure you that none of these proposals is utopian. Each is feasible, and not beyond our capacity and resources if the political will is there to implement it. God bless you."

APPENDIX XIX

A Confucian Perspective on the Rise of Industrial East Asia

by Tu Wei-ming

We envision the interplay of multiple themes across three broad areas of cultural interest: art and religion, morality and political institutions, and science and technology. Issues that are relevant to all these areas include the interpretation of literary, scriptural, testimonial and legal canonical texts; the historicity of human practice in art, ethics and science; the claim that traditional institutions make upon the present; and the legitimation of culture in terms of artistic creativity, scientific theory, or sacred and secular authority. Among the representative questions that could be addressed within the above framework, the following are pertinent: What are some of the central religious concepts of "self" that are evolving in Asia? Are "rights" necessary for a sound social-political order? What differing conceptions of justice, fairness and procedural due process might emerge in cross-cultural encounters? What models of "modernization" are most appropriate for developing societies? How can the traditional values of Asian cultures provide new directions for Western as well as Asian economic development?

1. The rise of industrial East Asia to become the most dynamic developing area of the world today is apparently due to the sustained economic growth of Japan and of the so-called "four dragons" (South Korea, Taiwan, Hong Kong and Singapore) in the last four decades since the Second World War. This phenomenon has fascinated economists, political scientists, sociologists and anthropologists. To the economist, the competitive edge of the Japanese exporting capacity in virtually all forms of sophisticated modern enterprise (with the notable exception of military hardware), the aggressiveness of the South Korean government in overhauling the infrastructure of its heavy industries, the ability of Taiwan to maintain a relatively equitable income distribution despite rapid growth, the nearly perfect market mechanism of Hong Kong and the well-calibrated measures of official intervention in Singapore pose intriguing questions at both practical and theoretical levels.

To the political scientist, government leadership, the process by which new policies are introduced and implemented, the patterns of authority that enable official directives to have broad popular support and the bureaucratic procedures that seem to have significantly undermined the principle of efficiency as well as other salient features of industrial East Asian societies provide food for thought. To the sociologist and anthropologist, the family-centered social structure, the clan organizations, the human networks based on numerous primordial ties, the relationship between the ruling minority and the populace, the educational system, the folk traditions, the interplay between rural and urban communities, and popular religions offer rich resources for generating new interpretive schemes and testing old ones.

2. Historians, philosophers and comparative religionists in their proving of the shared spiritual orientations of industrial East Asia, have identified a number of remarkably pervasive tendencies. These include the idea of the self as a center of relationships, a sense of the community of trust modelled on the family, the importance of an established ritual in governing ordinary daily behavior, the primacy of education as character building, the importance of exemplary leadership in politics, the aversion for civil litigation, the belief in consensus formation and the practice of self-cultivation. The value system that seems to be most compatible with these features is commonly labelled "Confucian ethics".

3. Yet, the claim that Confucian ethics has been instrumental in developing the functional equivalent of the "Protestant ethic" in East Asia will have to be

substantiated by a series of focused investigations; indeed, in addition to other relevant historical forces, i.e., Japanese colonialization, it is necessary to analyze the catalytic and intervening factors, such as the geopolitical situation, the labor market, international finance, American foreign policy, fear of Communist expansion, the institutional structure and the like.

4. Indeed a distinctive strength of these states is their willingness and ability to combine foreign science, technology and political organizations with institutional and spiritual resources from their own traditions. For decades the post-Confucian states have advocated the idea of going abroad to learn from the West firsthand as an important national goal. The most brilliant minds in these societies have accepted the fact that in a long-term perspective learning from abroad is essential for both social well-being and personal development.

5. At the level of central bureaucracy, although measures of democracy such as constitution, election and universal representation are widely accepted as defining characteristics of a modern polity, the basic Confucian idea that government assumes full responsibility for the well-being of the people remains persuasive in East Asia. Thus, in the post-Confucian states, governments are omnipresent, if not omnipotent. The idea that the central government has the responsibility to play a maximum role in the life of the people is predicated on the belief that politics is far from being a contractual framework for the purpose of providing law and order in society; comprehensive leadership is obligated, in a classical Confucian sense, "to provide, to enrich, and to educate" the people. Bureaucrats are not merely government functionaries but leaders, intellectuals, and teachers. The rise and fall of dynasties in imperial China often depend on the quality of its scholar-officials; so do the fortunes of modern states, as many East Asian intellectuals observe.

6. Japan's success in forming broad consensus, the conflict and tension between the central government and the intelligentsia in South Korea, Taiwan's relative progress toward an "open society," Hong Kong's ability to maintain a delicate economic and political balance despite obvious contradictions, and Singapore's style of one-party rule, divergent as they are, do not invalidate the basic premise that politics means comprehensive leadership and that the central government is the proper focus of power. The fear that total chaos may result if there is a fundamental restructuring of the top leadership is a daily anxiety. Any change in the key political players of the power game is of grave national concern.

7. However, this concerted effort to achieve vertical integration makes it difficult to develop Western-style democratic institutions and ideas such as civil society, loyal opposition, an independent legal system, rights consciousness, a sense of privacy, and individualism. As a result, the political pluralism that is needed for developing a full democracy is difficult to achieve in industrial East Asia.

Indeed, as Azra Vogel points out, the elite in Japan still believe that one of the highest callings is to become a bureaucrat. For the law school students at Tokyo University, the most competitive examinations are for those joining the major ministries in the central government.

Closely linked to this perception of politics as the arena in which vital decisions with long-term effect on the health of the nation are made is a strong belief in meritocracy through competitive examination. The faith in the malleability and improvability of the human condition through communal self-effort underlies East Asian educational philosophy. "Education without class distinction," a commitment that Confucius himself made to his students, has become an article of faith which assumes that public education, often administered by the central government, is a fundamental obligation of the leadership to the general populace. Since East Asian societies are hierarchically structure, education is, in practice, elitist but through the application of stringent standards of objectivity to all nationwide examinations, education also provides the best channel of upward social mobility as the universally accepted basis for leadership recruitment.

Since the primary purpose of Confucian education is learning to be human as a member of a "fiduciary community" (a community of trust), self-cultivation, the development of one's inner strength for the purpose of assuming responsibility for oneself, one's family, and society at large, plays a pivotal role.

The conflict between self and society can be minimized and a sense of mutuality enhanced if the participating members are willing to make adequate personal sacrifice to insure that egoistic desires do not significantly undermine the corporate spirit.

8. Indeed, the preference for a community of trust rather than an adversary system is so overwhelming that the paradigmatic practitioner in adjudicating conflict in the United States - the lawyer - does not play a key role in civil disputes in East Asia. Rather, mediation is often a preferred course for resolving disputes.

This emphasis on trust is particularly evident in local governance. The Confucian preference for self-reliance based on neighborhood associations with participation from a highly decentralized police organization is widely practiced. Major cities in East Asia are relatively safe because, in addition to strict gun control laws, life in these immensely populated metropolises is coordinated according to the modulated rhythms of a variety of small and essentially self-sufficient neighborhood communities.

9. Family, in the Confucian perspective, is an indissoluble basic unit of any civilized society. Primordial ties in the human community such as the five basic relationships (between ruler-subject, parent-child, husband-wife, siblings, and friends) are taken seriously as defining characteristics of being human. The centrality of the family in Confucian political, social and religious thought is a natural consequence of the Confucian imperative that self-realization takes communal participation as its point of departure.

10. Obviously, the rise of industrial East Asia raises fundamental questions about economy, polity, society, and culture in a global context. Economically, does this new capitalism, as contrasted with the classical capitalism originated in West Europe, signal a new age? Politically, are we witnessing a process of democratization based more on consensus formation than on an adversarial relationship which gives a new shade of meaning to participatory democracy? socially, do family cohesiveness, low crime rate, respect for education, and high percentage of saving relative to other industrial societies indicate an ethos different from the individual-centered "habits of the heart"? Culturally, are they successful examples of combining advanced technology with age-long ritual practices, or are they passing phases of traditional societies?

Do the new types of cultural awareness, partly as the result of new technologies, render obsolete the usual categories of "modernization"? For example, the successful computerization of Chinese characters renders highly problematic the old belief among westernizers in East Asia that the Latinization or elimination of ideograms is a necessary step towards cultural modernity.

Tu Wei-ming is Professor of Chinese History and Philosophy and Chairman of the Department of East Asian Languages and Civilizations at Harvard University. His communication was presented at the 1687th Stated Meeting held at the House of the Academy on January 13, 1988.

(Taken from the Bulletin of the American Academy of Arts and Sciences, Vol. XLII, No. 1., October 1988.)

APPENDIX XX

Special Academy Lecture

"Technology and the Future of Europe"

by Hubert Curien

Last fall, Hubert Curien, former President of the European Science Foundation and the European Space Agency, presented a special lecture at the House of the Academy on the relationship between the structure of the European economy and the advancement of scientific research in Europe. Professor Curien has also served as Director General of the Centre National de la Recherche Scientifique (CNRS), as President of the National Space Center and of the Air and Space Academy, and as French Minister for Research and Technology. The following is a summary of his remarks.

Many of you have visited Europe, and are aware of the difficulties which Europe faces in coordinating its economic and scientific activities. I would like to present a short analysis of this problem with a particular emphasis on the implications of scientific research for the economy of the European continent as a whole.

To strengthen the bonds between scientific and economic progress, Europe must deal with a number of short-comings. Among the most serious is the lack of an effective common market. It is true that what we term the "Common Market" will be formally established in 1992, but for the present we must accept the fact that our activities in technological development are redundant. The same kinds of products and systems are being developed independently in every major country in Europe. If we are to make our science and industry more efficient, we must begin to move toward greater cooperation. Europe must also find ways to encourage innovation within its small to middle-sized industries. The common practice in Europe is for large industries to subcontract to smaller firms, indicating exactly the type of inventions and products they want. Consequently there is little need for smaller firms to employ good scientists and engineers, and innovation is circumscribed within a few enterprises.

On the financial side, the European use of capital has not been directed toward support of innovative practices. Some positive changes are being made in this regard; for example, we have collected a number of legal rulings which should stimulate venture capital, and large banks throughout the continent have sought the advice of scientists and engineers on possible investments. Again, it will take time to change the attitudes of a citizenry, and especially a banking community, that has traditionally demonstrated little interest in innovation. Related to the limited availability of private capital is the fact that Europe has no institution analogous to the United States Department of Defense, which invests a large percentage of its enormous financial resources in research carried out by American universities and industry. In Europe each country supports its own defense effort, and the percentage of funds allocated for research is much smaller. Of the federal funds presently dedicated to research in the United States, some 72 percent comes from the Department of Defense as compared to 50 percent in the Untied Kingdom, 30 percent in France and 10 percent in Germany. Although military funding may be controversial, diminishing it would not increase the budget for research in civilian ministries, and greater allocations from the defense budgets would enable European countries to expand their research efforts significantly.

There is the further issue of the role of research within European industries and universities. The leaders of European industries tend to be oriented toward marketing and production rather than research. On the other hand, academic research is not closely linked with industrial needs. To help reverse this situation, an effort has been made to include a "Mister Research" on industrial boards of directors. The reasons for the separation of industry and academia vary from one country to another. In France, for example, it is the engineers who generally become the industrial leaders of the nation, yet they are educated in schools which allow them only very limited access to laboratory facilities, and thus they bring virtually no research experience to their influential positions. Research scientists, in turn, are trained at the universities which have excellent laboratory facilities, but these scientists tend to become teachers or researchers as such and are seldom found in important decision-making positions in industry. Here again we are faced with traditions that must be changed. ...

Now let us examine what we have achieved in Europe, first in terms of such "big programs" as aeronautics, space, and atomic energy. I was fortunate to have been in a position of responsibility for space activities in France and Europe during a particularly exciting period. With the development of one launcher, Ariane, we now hold more than one-half of the market for orbiting satellites - a considerable success for Europe. The story of Europe's involvement in space is an interesting one because we started very early and very badly - just after Sputnik, some thirty years ago. Charles De Gaulle was the President of France, and he had decided that the French must have a part in space activities. We tried to convince our neighbors to launch a common European effort, but the result was not what we expected. A three-stage launcher was conceived, with Britain producing the first stage, France the second, and Germany the third. Although there were no problems with the individual stages, they failed to work together because there was no unity of conception. The project was an example of juxtaposition rather than integration, and it epitomized Europe's inability to bring about significant scientific advances.

In the 1970s, Europe achieved some very real success with the formation of the European Space Research Organization (ESRO) which built seven scientific satellites to study the magnetosphere and the ionosphere. However, the European governments felt that the future of satellites lay not in the areas developed by ESRO but in telecommunications and observation, and thus ESRO was disbanded.

In its place, we established the European Space Agency with the two-fold purpose of "encouraging strong scientific activities" and developing satellites and launchers for specific applications, including telecommunications and observation. Support of the scientific programs is mandatory, with the contribution of each of the eleven participating countries determined by its GNP. Support of programs focused on specific applications is termed "a la carte". For example, France chose to take the lead in the development of the launcher, Ariane, providing 66 percent of the funds while Germany contributed 10 percent, Italy 10 percent, and Britain about 3 percent. whereas Ariane is a completely European endeavor, a second project, Space Lab, is a European-built laboratory to be launched on an American shuttle. In this case, Germany has taken the lead and has chosen to involve the United States because it maintains that the goal of advancing fundamental research in this area cannot be accomplished without the expertise and active participation of America. Space Lab appears to be a magnificent facility which works very well, but given the problems and priorities of NASA, there remains the question of when it can actually be launched.

Ariane and the Space Lab raise the question of the extent to which European space activities should be autonomous. In the late 1960s and early 1970s, France and Germany built two telecommunications satellites under a program called "Symphonie." But since Europe lacked it sown launching capabilities, it had to request that the United States put the satellites into orbit - a request honoured by the United States on a commission basis. This was, of course, a fair arrangement for a commercial venture, but it points up the fact that without autonomy in its launching facilities, Europe can never be commercially active in space.

Nonetheless, by the mid 1980s, a number of successful European space programs were in place - Ariane, Space Lab, telecommunications and observation satellites. At that point, the principal issue was whether to advance gradually by building a more sophisticated version of Ariane or to take a giant leap by adopting a British plan for the construction of one of the world's first horizontal take-off launchers (Hotol). Given the uncertainly over the feasibility of "jumping over" an entire generation of launchers, it was decided that the French would proceed to design and build a larger, more reliable Ariane, known as Ariane 5, while the development of the Hotol system remained under study. ...

In all of these undertakings, the critical link between European science and the economy must not be overlooked. ...

To stimulate networking in market-oriented enterprises, a program entitled Eureka has been formed. Under Eureka, a product with a projected development time of 5-10 years is identified and analyzed, with particular emphasis on the approach needed to make it marketable. Eureka's first principle is to avoid the redundancy which has hindered both innovation and efficiency in Europe's technological growth. The second principle is "variable geometry" - a practice that is difficult to achieve in an organization such as the European Economic Community which tends to promote the proportional participation of every country involved. Since each nation has the right of veto, quick decisions are impossible to obtain. The main purpose of "variable geometry" is to avoid the right of veto for each project by considering the program as a whole and by granting each country reasonable participation in the total effort. The third principle is to work from the "bottom up" as opposed to the "top down", to search for the best ideas and encourage initiative from individual countries and industries rather than to issue directives from above and stifle, or fail to respond to, the most inventive proposals.

In sum, Europe is striving to advance both its science and its economy through integration and innovation. Yet in seeking to become more autonomous, we are not trying to distance ourselves from the United States. Quite to the contrary; it is our firm conviction that a strong Europe will be best for the United States as well.

(From the "Bulletin of the American Academy of Sciences," Vol. XLI, No. 8, May 1988)

STATED MEETING REPORT
Policy for Science in 1989 for the USA:
A Public Agenda for Economic Renewal

by Lewis M. Branscomb

It is my contention that scientific progress in the post-World War II period has transformed the relationship of science to engineering and of both to innovation and production. These changes have much of their origin in U.S. science, yet both industry and government have been more responsive to these changes in Japan than in the United States.

When Americans return from our holiday from reality we will discover that science and technology, together with the wisdom and imagination to manage them properly, have become the new force in global change - a force that can allow America to participate in global growth. But we must also understand that science has changed the way technologies are generated and applied, and has done so in such a way as to enhance the economic value of strong science, provided it is coupled to strong engineering.

De Facto Policy on Science and Technology

In the United States there is no political consensus on the implications of rapid technological change or on the federal government's role in applying the forces of technological change to economic advantage. In this climate the call for a national science and technological strategy generates fears of "industrial policy", itself an ill-defined cliche for unwanted federal influence over capital markets and commercial technology.

But even in the absence of the interventionist industrial policy most feared by business leaders, there is widespread skepticism about the federal government as an instrument for encouraging change-threatening innovation. These doubts are most eloquently expressed by Rosenberg and Birdzell: "In well-ordered societies, political authority is dedicated to stability, security, and the status quo. It is thus singularly ill-qualified to direct or channel activity intended to produce instability, insecurity, and change."

Yet despite such concerns it is demonstrable that the United States has a de facto technology policy, which, for better or worse, has major effects on the innovation rate and competitiveness of private firms. This policy is based on six important political principles:

1) Private industry draws its technological stimulation from the incentives of a competitive market, although it rests on a technology base provided more or less equally by government and industry and on a science base provided largely by government.

2) The federal government's primary technological responsibility is for national defense and related federal missions. The government purchases 40 percent of the R&D capability of the United States and applies 70 percent of it to military purposes.

3) Because education is constitutionally a state and private responsibility, federal support for higher education in science and technology relies heavily on indirect support through research as well as student aid. Together with industry's investment in defense-related R&D, some 35 to 40 percent of the national R&D effort is defense-related.

4) Government regulation and court actions are assumed to create market incentives sufficient to generate privately funded technology to protect health and safety at an affordable cost.

5) Fundamental research in science is a public good and should be funded by the federal government, primarily in universities, in cooperation with state and private sources.

6) Vitality and creativity of science and technology are enhanced by scientific autonomy and by federal restraint in both industrial technology and control of

higher education. This tradition of decentralized initiative draws strength from principles of intellectual freedom rooted in the Bill of Rights.

Implicit Assumptions in Science Policy

These principles have led to a decentralized and relatively unbureaucratic government support system for science. Government science and technology programs applied to specific economic objectives have been limited and most often unsuccessful. When there was plenty of money from both government and business, this system proved to be the world's strongest for encouraging creativity and technical progress. Implicit in the applications of these principles in the past, however, are four increasingly suspect assumptions:

1) A linear model of the innovation process has been used to justify an increasingly unrealistic view of basic science and of product development and production as sequential, loosely coupled processes. Basic science is seen as leading to discoveries, which may be transformed through applied research to engineering prototypes, which in turn are taken up by production engineers and manufactured.

It is often said than Vannevar Bush, in *Science, the Endless Frontier*, based his case for limiting federal support to basic science on this linear model, but there is little evidence for that. Bush was a very practical Yankee engineer and doubtless knew better. But the success of his policy encouraged others to give the linear model more weight than it deserves.

A subordinate consequence of the linear model is that engineering proceeds independently of science once it has absorbed the results of science research. In 1985 private industry performed 73 percent of the nation's R&D, 97.7 percent of which was applied research or development, according to the National Science Foundation (NSF). It is not surprising that many regard engineering research support as the province of industry and of the mission agencies of government. The President of our National Academy of Sciences, for example, argued in 1985, when he opposed changes in the NSF enabling statute that made engineering symmetrical with science, that NSF should give priority to the support of science, since "mission-oriented" agencies provided funds for academic engineering. As a practical matter, this policy would leave support of academic engineering largely to the Department of Defense and NASA.

The linear model thus seemed to support the effort in Congress, lead by George Brown, to create a National Technology Foundation that would parallel the NSF but be devoted to engineering. This was opposed by the National Science Board as competitive and divisive at a time when increased integration of science with engineering was emerging as the correct national strategy. But neither the issue nor the proposal has faded away, since the National Science Board has never declared how far toward the "downstream" areas of engineering the NSF should go. Nor has any other agency of government, except perhaps Defense, stepped up to accept responsibility for the modernization of fundamental engineering education and research.

2) The bifurcation of the national technical enterprise into a private commercial economic sector with little public R&D support and a military sector receiving the majority of federal R&D investments implies the viability of a two-economy model for the national technology base. Do these two economies support and share the same base? Is our civil economy bearing an enormous opportunity-cost from this policy?

The prevailing political view, based on military and, more recently, on large space and energy projects, gives rise to a spin-off or trickle-down model for their technological value. Technology benefits from large and very complex engineering projects, such as the Apollo program, the space station, or the aerospace plane, arise from the notion that new science should be first introduced into technology in a highly sophisticated application in which unique new function can justify high cost. Thereafter, in keeping with the linear model idea, engineers find ways to decrease cost and apply the technology to less demanding applications. This is the trickle-down theory of technology introduction. It has dominated U.S. government and industry practice in the recent past. For example, in IBM, the largest computers have borne the cost of new microelectronic technology introduction, which in due course found its way into high-volume, low-cost small computers.

This view of megaprojects as catalysts for conversion of new science into trickle-down new technology gives them status as public goods. By analogy with basic research, they may be thought of as basic technology. In fact, their objectives are often diffuse, and their political attractiveness derives in large measure from the aggregation of great political benefits in visible, geographically concentrated packages.

The Japanese have demonstrated an alternative to the trickle-down strategy for introducing new science into technology. In consumer electronics, their engineers practice "trickle-up," bringing new scientific discoveries first into low-cost consumer products but at design points that do not stress the function of the new technology, keeping risk and costs low. With learning gained in production, they gradually increase the function and decrease the design margins until the technology is ready for more demanding, higher-profit business and industrial applications. With this strategy they have found a wholly new way to combine science and engineering and gain substantial competitive advantages.

3) The strength of the argument against federal industrial policy depends less on fundamental principles and more on the inequality of power between the federal government and the individual firm, pressures for egalitarian distribution of benefits, and the government's reputation for budgetary profligacy. Direct assistance to industrial technology for economic purposes has been more acceptable when conducted by state governments. The rapid growth of state activities is now compelling the federal government to acknowledge and accommodate them. An example can be found in the 1988 Trade Bill, which charges the National Bureau of Standards to help states' efforts to enhance manufacturing technology in private firms and changes the Bureau's name to National Institute for Standards and Technology.

4) A final assumption has been that R&D activities are judged as alternatives to other elements of each agency's activities, so that budget trade-offs are not to be made among the R&D programs in different agencies but only between R&D and non-R&D components of agency activity. Thus, there is no R&D budget constructed by the Office of Management and Budget prior to the President's annual decision; it is constructed after the fact. This insures decentralization of control but permits great variations in cost and value standards for technical programs.

A corollary of this view of the fungibility of research is weak management control at the level of the Executive Office, which leaves federally funded R&D decisions to a combination of the autonomous decisions of the scientific community, the ambitions of the agencies, and the political destiny of these ambitions when they reach the Congress.

Changing Paradigms for Science, Engineering and Innovation

One impact of the competitiveness debate on science policy has been to cause a reexamination of these implicit assumptions that have served as rationales for the current policy. The most important changes relate to models of the innovation process, to the relationship between science and engineering, and to the way one thinks about the distinctions between basic and applied research.

Science

The biggest changes in technology have come from the impact of science on engineering, but first let me note that only recently has most of science become "scientific." At the time of World War II, most of biology, much chemistry, and applications of physics to chemistry and condensed matter were largely empirical. Physics was farthest advanced, but even in that field, Professor Otto Oldenberg (my thesis adviser at Harvard) could complain, as he prepared to abandon research in plasma physics in 1949, "All the phenomena have been explained, but none have been predicted."

Changing Nature of Engineering

Distinctions between science and engineering are beginning to fade. Once highly empirical, engineering has become "codified." After World War II, U.S. universities, with strong help from federal agencies, set about inoculating the field of engineering with a strong dose of science. The results, when combined with the maturing of the computer, have been quite spectacular.

Engineers who used to depend primarily on models and empirical analysis are moving to synthetic approaches. This is made possible by scientific advances in the characterization of matter and materials. With extensive quantitative knowledge of these properties and with the measurement skill to characterize them, engineering problems can now be solved by the synthesis of existing knowledge embodied in computer simulations.

Manufacturing

This codification of engineering affects more than research and development. Its most important economic effect is to permit the simulation of processes and designs and their qualification for manufacturability (again, providing the materials and processes are quantitatively characterized). The resulting electronic data can then be used to drive automated, intelligent manufacturing equipment, thus integrating the functions of design and production engineering and substantially accelerating the product development and production cycle.

Once high-tech materials and processes are in manufacturing, scientists and engineers may have to recharacterize and change the processes, for they may be highly dependent on details of the production environment. The result is that the innovation process is better described as an interactive, interdependent process in which manufacturing, design process, and product development all drive, as well as draw from, research effort, and in which all are in close contact with the fundamental science knowledge base. The case for the interactive model of innovation has been extensively explored by Kline and Rosenberg, Utterback, and others. The new approaches to production technology and its relation to science only reinforce the correctness of their view. Building a national science policy for competitiveness on such a model forces one to focus on the relationships of engineering and science as both products and sources of technology.

The Relationship of Science to Technology

It is a commonly held fallacy that scientific progress leads naturally and inevitably to technological progress. The correct way to view today's relationship of science to technological progress is to understand that a rich fund of scientific tools expand enormously the variety of possible technological responses to any problem. Thus, technology increasingly avails itself of science at every step of the innovation process: conception, design, development, production engineering, production, testing, and field support.

Causes of Innovation

If science is indispensable to innovation but does not cause it, what does? An important driver of innovation is technical understanding that the older technology's limitations are about to jeopardize the rewards that have driven the investment strategy to that point. Put another way, it is the refusal of the innovators to accept reality as inevitable.

Charles A. Berg suggests that an "innovation consists of a discontinuity in the concept of production." He notes that the heart of the innovation is novelty in solving the problem, not necessarily economy compared with current practice. The innovator wants to get off of one learning curve and onto another, even if the initial cost penalty of the jump is severe and the risk high. His eye is on the future; he wants nature on his side.

Thus, the reintegration of science and engineering has a number of consequences for the process of innovation and the transnational diffusion of innovation capability, as well as for the practice of the profession itself. Science, having become scientific, has made engineering engineerable. The result, however, is an increased tension in the technical community as we try to sort out the appropriate federal role for the support of science and engineering. Let us take note of the main sources of this tension.

1) *Financial squeeze on R&D.* The first source of stress is budgetary. There is no crisp definition of the "discretionary" portion of the federal budget, but in practical political terms it has been estimated as about 25 percent of the total. Of this amount, 27 percent is R&D - i.e., 6.7 percent of the total budget. Thus, even if there is no conscious trade-off between R&D programs in different departments and agencies, it happens in the appropriations subcommittees of the Congress. The NSF's first step toward budget doubling, for example, was the victim of a trade-off between housing subsidies in the Housing and Urban Development budget, the replacement of the *Challenger* space shuttle, and the NSF research appropriation.

This squeeze on the total federal resources available for science and engineering is exacerbated by the recent initiation of a number of megaprojects ranging in peak annual cost from hundreds of millions to billions of dollars. It is doubtful that the government will be able to find in the discretionary budget enough money to cover the peak funding rates for the projects already started, such as the space station, the superconducting supercollider, and the aerospace plane - much less to initiate a number of others, such as the program to sequence the human genome.

The fires have been relit under the historic conflict between "big science" and "little science." "Little science" is no longer little. A single investigator in chemistry or molecular biology today needs access to many scientific instruments, each costing between $50,000 and $.5 million. The failure of the federal government to have a capital budget for science assures that not only does mega-science compete with mesoscience, but facilities compete with operating costs at every stage.

2) *Science versus engineering.* The second source of stress is between science and engineering. The attachment of the science and technology policy debate to the economic competitiveness issue is the basic source of the stress. Advocates of science have long argued that science is the key to long-term economic opportunity. They are, of course, correct. but the lock in which that key must turn is engineering, and while engineering is becoming increasingly dependent on science, it is also failing to produce competitive products in America's design shops and factories.

Indeed, to an important extent it is the failure of industrial engineering to be technically imaginative that has created America's competitiveness problem. The evidence is strong that Japan's and Germany's manufacturing productivity and quality and shortened production cycles, together with speed of iteration of design and process improvements, have given those nations a strategic advantage.

Much of the U.S. problem must be laid at industry's door. The American factory is usually run with a low-tech attitude, even if it is chock-full of high-tech equipment. To the extent that the cure lies within the control of universities, it is the "downstream" areas of engineering - design for manufacturability, process development, production systems engineering, measurement and characterization of materials and process, and the associated education - that need improvement. Engineering schools and factories will have to work together to improve the factory's image and attract bright students into production-related careers.

The answer is not to divert funds from science to engineering but to invigorate design and production engineering so it is capable of leveraging a growing body of scientific knowledge. This goal, of course, can only increase the already severe pressure on federal budgets.

The fundamental rationale for government support is the creation of values to society that exceed the benefits captured by private companies in price or in other commercial assets. In economic terms, these values are externalities, or corrections for market failures. Basic scientific research is the most obvious example of such externalities, or corrections for market failures. Basic scientific research is the most obvious example of such externalities, but there are many others: training, standards, publication of scientific and engineering data. To this list should be added fundamental, nonproprietary research in the downstream areas of engineering.

Is it appropriate for the federal government to try to help engineering performance in industry through its R&D and education activities? To answer, we must address three questions.

1) Is the problem in U.S. industry only one of management, or is there an intellectual challenge for which advanced research and higher education are required? The National Science Board concluded that the latter was the case in their 1983 review of NSF policy for engineering. University and company research in engineering materials, computer graphics, robotics, and manufacturing systems engineering suggests that there is ample scope for major technical progress.

2) The second question is, Can we define tests for appropriate work in science or in engineering that avoid putting the government in the position of doing applied problem-solving work for industry or simply replacing private dollars with public ones? The answer is yes, by applying to engineering research the same criteria used by the NSF for fundamental work in science: that it is timely, adds to knowledge, is unlikely to be funded by industry, and scores high for its intellectual value or application potential or both.

Considerable confusion surrounds the way these criteria are used, in part because the NSF's budget categories - basic research, applied research, and development - are defined in terms of the motives of the investigator, not the expectations of the investor. Thus, if NSF avoids funding applied research - as it should in most cases - all of its work falls into one category, basic research, whether its potential application will occur relatively soon or far in the future.

The General Accounting Office has criticized the inadequacy of the NSF taxonomy of technical activity for budget purposes. The GAO proposal suggests the need for two budgetary categories of research investment in the nation's technology base: fundamental research (combining basic and generic, applicable research) and mission-targeted R&D, which splits out the costs of R&D efforts specific to the accomplishments of agency missions. Fundamental research would be classified as either basic and strategic or generic. Engineering research in NSF would fall largely in that latter category.

3) The third question is, Should support for engineering and scientific research share the NSF's resources or be institutionalized separately? Many in the engineering community believe that the federal government can contribute to the modernization of engineering without improper interference with private markets. On the question of how this is to be done, some would support the NSF's efforts to expand support for engineering and technology-related science while trying to protect more basic research at the same time. Others would prefer to see NSF left as is and to create new agencies for addressing non-defense engineering and technology directly. Neither alternative is without severe difficulties.

One proposal is embodied in Senate 1233, which was Title 40 of the Trade Bill until April 1988. The National Bureau of Standards is to be reborn as the National Institutes of Technology in the Department of Commerce. In addition a new agency, a "Civilian Defense Advanced Research Projects Agency," is to be created and called the Advanced Civilian Technology Agency. Other alternatives are the National Technology Foundation or even the much-criticized Department of Science and Technology.

For its part, the scientific community is also divided. Many scientists - perhaps most - believe NSF should be left as it is, even if the case for rapid budget growth is weakened. Others would welcome the priority attention stemming from economic concerns and would base their hopes on realizing the President's plan to double the NSF budget for science and engineering together.

I have presented arguments that both the creation and the diffusion of technology are affected by scientific trends in engineering practice and that countries rich and poor are asking how government can help the knowledge-intensive (high-tech) industries as a source of foreign trade.
What should we Americans do about it? Let's try nine ideas; then I am done.

A Global Strategy

First, our strategy must be a global strategy. We have more to gain from access to world resources, markets, and human talent than anyone else. We must keep the trading system open, fair, and efficient. World growth and world markets should be our goal.

Appropriating the benefits of science. We also need a commitment shared with other industrialized nations to sustain the world supply of fundamental science and engineering knowledge. Brooks has suggested that every industrial country will be increasingly eager to emulate Japan and Korea, investing their scarce technical resources in applied science and in engineering, drawing on the store of fundamental science provided by those countries that make the largest investments in it - most especially the United States.

If countries in a rapid catch-up phase of industrialization can draw on science done elsewhere without having to practice the research in order to learn its art, then it becomes even more difficult for the nation doing the fundamental research to appropriate its benefits. But the technical leaders have no choice. Their science drives progress in all phases of their technology, which must provide the productivity that sustains high living standards.

The net result of many nations trying to live off of the table set by their competitors could ultimately be a downward spiral in national investments in basic science, to the detriment of worldwide technical progress and economic growth.

Political leaders of nations must be induced to think of the world pool of knowledge as a common resource to which each must contribute as well as draw.

If all nations invest in their appropriate share of fundamental science and engineering, a commitment to unfettered scientific communications and travel may be sustained. Unfortunately, in addition to the restraints of technology export controls for national security reasons, the alternative strategy of intellectual protectionism seems to be gaining support. The pool of knowledge is threatened with becoming a lot of separate puddles.

Taxonomy of R&D

Having established the need for an open system of science and engineering, Americans must adopt the correct distinctions between open, nonproprietary research that qualifies as a public good and the market-specific, proprietary development that should be performed in and paid for by private firms. The debate over appropriate roles for government investment should be seen as generic versus appropriable research, not as science versus engineering.

To translate this into federal budget allocations, the federal government should update and make uniform across all agencies, civil and military, the definitions used to delineate the taxonomy of R&D activities, in order to communicate more clearly about all the types of research for which federal support may be appropriate.

The Japanese notion of what "fundamental" means is broader than the accepted American notion. It includes what the Department of Defense calls 6.1, or basic research. But it also includes exploratory development and proof of principle of new technologies, which some call strategic research and which fits much better into the budget categories 6.2 and 6.3A than in the basic or applied research categories used in the NSF and other civil agencies. These classifications of work can be entirely appropriate for the NSF or other agencies to invest in, in the interest of economic growth and productivity improvement.

Defense and the National Technology Base

Third, we must face up to the consequences of trying to compete with the Soviets and the Japanese simultaneously with public and private R&D efforts, neither of which contributes as much as it should to the other. Over two thirds of the federal government's expenditures now go into military projects. Yet in spite of this and the reluctance of commercial businesses to welcome federal help in R&D, there are many areas in which the commercial technology leads the military by years. And as I have already noted, there are styles of engineering, such as the "trickle-up" approach, from which defense as well as commerce might benefit.

To the extent defense strategy is shifted away from unique, futuristic technologies of enormous cost and highly uncertain value, back to greater reliance on evolutionary modernization of reliable weapons mass-produced to permissive costs, greater dependence on the commercial industrial base may be possible. Government, on behalf of its defense interest, should expand its investments in fundamental and strategic research and education as its contribution to that industrial base. This should be done not through defense research agencies alone but through growth of the core funding agencies concerned with the economy as well as with national security.

Research Investment Priorities

Thus, we need a unified strategy for investing in the national research base, both to increase industrial competitiveness for civil markets and to sustain the capability of the defense industry. The Japanese have already begun a major expansion of their non-proprietary fundamental research. They have the money and the incentive. I believe the Japanese will do very good work and will not be held back, as many believe, by their culture's lack of emphasis on individual creative achievement. Americans must make sure that our research remains fully competitive.

We must also recognize the importance of investing in research and scientific services to enhance R&D productivity as well as innovation. An effective science and engineering information distribution system with strong secondary literature that provides the evaluation of quality and the adaptation of knowledge for use are essential elements. The concept of what we mean by "research as a public good" should embrace the infrastructure of knowledge, tools, and processes that sustain all innovations, both conceptual in science and substantive in engineering.

Much of this work is not as glamorous as forefront conceptual advance in science. Agencies like the National Bureau of Standards may be more appropriate sponsors for it than the NSF. But a 2 percent increase in industrial R&D productivity would increase R&D output by $1.3 billion, an amount equal to the entire NSF research appropriation. The fact that R&D productivity cannot be measured is not an acceptable reason for not trying to improve it.

Finally, the government must adopt a much more rigorous means of evaluating and justifying megaprojects. The scrutiny such programs receive seems proportional to a fractional power of the cost. This is not only wasteful but discredits the scientific case for capital facilities of great scientific potential. The political magnetism of these billion-dollar programs impedes that evaluation, suggesting the need for a formal process of public review by qualified bodies responsible to the public and to Congress and required to make comparisons with alternatives.

How Much is Enough?

How much public investment in science and engineering research is enough? There is no formula, but there are tests to guide judgment. Comparison of U.S. investments in nonmilitary R&D as a function of non-defense national product with those of other nations, especially Japan and Germany, shows the United States spends only two thirds as much on nonmilitary R&D as Japan. With no evidence that our R&D productivity is superior, we seem to be underinvesting. U.S.-born graduate students in science and engineering lag behind foreign students in number and quality. With the defense industry preferentially choosing U.S. citizens from a demographically diminishing pool, the civil sector is going to be shorthanded. Finally, government should try to induce industry to assume as much of the cost of the research for the national science and technology base as possible, both in-house and in universities. This can be done with matching grants, with the R&D tax credit, and with other tools. The response of industry to the government's technical initiative is another measure of the adequacy of federal investments.

Research and Education for Competitive Production

Special attention is needed from both industry and government to put the technical challenge back into careers in design, process development, and manufacturing systems engineering, balancing the emphasis that must continue to be given to R&D. This will require both curriculum development in universities and change in the way companies staff and manage their factories. Should the NSF try to take leadership for this mission? I think the NSF can invest in the intellectual roots, as suggested above, but I do not think the NSF should be tasked to undertake the reeducation of American workers, engineers, and managers for a competitive industry. A new resource, perhaps in a rebuilt Department of Commerce, may be the only answer. "If this be industrial policy, let them make the most of it," as the saying goes.

Public Education

Seventh, in case you are counting: From a long-term point of view, our most serious handicap is a system of public education that in many places is in functional bankruptcy. Science teachers are disappearing from our schools. We are graduating people who cannot reason out problems or understand the instructions on the use of today's tools. They are grievously ill-prepared for tomorrow's world of intelligent machines, which they must supervise.

The latest scorecard of U.S. student performance in science achievement tests ranks our fifth-graders 8th from the leaders, who are, of course, Japan and Korea. Our ninth-graders rank 15th out of 16, in a tie with Singapore and Thailand but ahead of Hong Kong.

In the next five decades 38 million Americans - almost all from educationally and economically deprived minorities - will come into the work force. They must receive an education far superior even to that now offered in the white middle-class suburbs. While this is no the main focus of this lecture, there is no more urgent matter to be attended to; yet solutions will take years to take effect.

Business Management

Eighth: Most of America's industrial problem is not government's performance but the lack of incentive for industrial companies to stay the course on learning to use science and engineering to be competitive manufacturers. To be the hollow corporation selling imported products in the U.S. market is the easiest path once a company has become uncompetitive.

Government must find ways to change to rules of financial punishment and reward to induce industrial companies to compete as producers. A capital gains tax on industrial equities that scales from high for short-term gains to zero for gains held more than three years might change the way CEOs view strategic investments in human resources, technology, and new plants and equipment.

Management Support and Program Evaluation in the Office of Science and Technology Policy

Ninth: The Executive Office of the President must have the capability to balance the demands placed on the national research and engineering capability with the investments made to sustain and grow it. I have also called for a defense strategy that maximizes its dependence on a shared national technology base. The trade-offs can only be made by an Office of Science and Technology Policy with the power to influence agency budgets to produce a sound national program of public technical investment to support and complement the efforts of private industry.

In summary, science and engineering are not mysterious forces that should be treated as some kind of alchemy best dealt with by pretending that chance, politics, and the courts can do a better job of management and investment than informed people making rational decisions.

I believe it is time to try to manage the government's technology affairs competently, even at the risk of failure, in order to forestall the prediction that we will indulge the luxury of lapsing into a "second-rate agrarian society."

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