SCIENCE, SCIENTIFIC COMMUNITY AND DEVELOPMENT*

BY
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The major theme of my remarks today is the importance of acquiring science in addition to technology. I shall be arguing that science transfer must accompany technology transfer for meaningful development of any society. I will argue that Kenya has reached the stage when it should be putting its emphasis on science transfer and on creation of new science.

I have been in Nairobi three days now. During this time, I have had the privilege of discussions on the role of science and technology with the vice chancellor, the principal and the dean, besides heads of Departments of Physics and Mathematics. I have had discussions with the chairman and members of the Council of Science and Technology, with staff of the International Centre of Insect Physiology and Ecology (ICIPE) and with the directors and staff of the international organizations of the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the United Nations Environment Program (UNEP) and finally, with the Minister of Education, Science and Technology. Let me begin by congratulating all of you on the quality and sophistication of the university departments, on the creation of a National Council for Science and Technology, and the allocation of priorities this council has determined in respect of agriculture, forestry and natural resources.

I also wish to congratulate you on attaining such high literacy standards in such a short while after independence. This high rate of literacy--and particularly scientific literacy--is the first condition of a true development in science and technology. I must also congratulate the government on creating an international centre like ICIPE with its international standards of scientific creativity and finally for providing facilities for the international scientific organizations like the Regional Office of UNESCO and the UNEP organization. I was privileged to hold discussions with the Director of UNEP, my old friend Professor M. Tolba, and with my colleague and friend, Professor D. Bekoe, the Director of the UNESCO Office. I mention these UN initiatives, because, as you may

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expect, the bulk of my talk will be devoted to the international aspects of science and technology, with a description of the Centre in Trieste which I am privileged to direct.

But before I do this, let me emphasize that science and technology is the shared heritage of all mankind, south and north, east and west. To illustrate this, let me start with the story of a young Scotsman who left his native glens to travel south to Toledo in Spain some seven hundred and sixty years ago. His name was Michael, his goal to live and work at the Arab Universities of Toledo and Cordova. Michael reached Toledo in 1217 A.D. Once in Toledo, Michael formed the ambitious project of introducing Aristotle to Latin Europe, translating not from the original Greek, which he did not know, but from the Arabic translation then taught in Spain.

Toledo's school represented one of the most memorable of international essays in scientific collaboration. To Toledo came scholars not only from the rich countries of the South and West, like North Africa, Egypt and the Sudan, but also from developing lands of the West like Scotland and Scandinavia. Then, as now, there were obstacles to this international scientific concourse, with an economic and intellectual disparity between different parts of the world. Men like Michael the Scot were singularities. They did not represent any flourishing schools of research in their own countries. With all the best will in the world his teachers at Toledo doubted the wisdom and value of training him for advanced scientific research. At least one of his masters counselled young Michael the Scot to go back to clipping sheep and weaving woolen cloths.

In respect of this cycle of scientific disparity, perhaps I can be more quantitative. George Sarton, in his monumental five-volume *History of Science* chose to divide his story of achievement in sciences into ages, each age lasting half a century. With each half century he associated one central figure. Thus 400--450 B.C. Sarton calls the Age of Plato, this is followed by half centuries of Aristotle, Euclid, Archimedes and so on. From 600-650 A.D. is the Chinese half century of Hsiian Tsang, from 650-700 A.D. that of I-Ching, and then from 750-1100 A.D.--350 years continuously--it is the unbroken succession of the Ages of those from the South, Jabir, Khwarizmi, Razi, Masudi, Wafa, Biruni and Avicenna, and then Omar Khayam. After year 1100, appear the first Western names: Gerard of Cremona, Roger Bacon, Jacob Anatoli. But the honours are still shared with the names of men from the South. No Sarton has yet chronicled the history of scientific creativity among the Africans or the pre-Spanish Incas, Mayas and Aztecs, with their diverse pharmacological discoveries, including arrow poisons and quinine, and the discoveries relating to the calendars of the moon and Venus, but the outline of the story is the same--one of undoubted superiority to the Western contemporary correlates.

After 1350, however, the South and the East lose out except for the occasional flash of scientific brilliance, like that at the Court of Ulugh Beg--the grandson of Timurlane, in Samarkand around 1400 A.D.; or of Maharaja Jai Singh of Jaipur in India in 1720--who corrected the serious errors of the then Western tables of eclipses of the sun and the moon by as much as six minutes of arc. As it was, Jai Singh's techniques were surpassed soon after with the development of the telescope in Europe. As a contemporary Indian chronicler wrote: "With him on the funeral pyre, expired also all science in the East." And this brings us to this century when the cycle begun by Michael the Scot turns full circle, and it is we in the developing world who turn westwards for science.

However, during this century, in the world of physics, we start with the name of Sir C. V. Raman of India--the physics Nobel Laureate of 1930; and of the Chinese Lee, Yang and Ting. During 1979, the Nobel Prize was also awarded to the West Indian economist, Sir Arthur Lewis. In 1983, the physics award went to C. V. Raman's nephew, Professor Chandrasekhar. In addition there has been the award of the Nobel Prizes to the Indian biologist, Professor Khorana, the Venezuelan Professor Benacerraf and the Argentinian, Professor Leloir. Last year when we constituted the Third World Academy of Sciences, we identified 43 Third World scientists whom the prestigious academies of the West--like the Royal Society, the National Academy of Sciences of the USA, the USSR Academy of Sciences, the Pontifical Academy--have honoured by making them members. Among them are five Africans, including the Kenyan, Professor T. R. Odhiambo, Director of ICIPE, and Professor D. Bekoe of Ghana, the Director of the UNESCO Centre in Nairobi.

But in saying all this and emphasising the contributions of those from the Third World, I do not wish to be parochial. As Al-Kindi wrote 1100 years ago: "It is fitting for us not to be ashamed to acknowledge truth and to assimilate it from whatever source it comes to us. For him who scales the truth there is nothing of higher value than truth itself; it never cheapens nor abases him."

Now, in this context, the question we must ponder is this: are the developing countries today firmly on the road to a renaissance in sciences--as the West was in the 13th Century at the time of Michael the Scot? Unfortunately, the answer is "no". There are two prerequisites to this renaissance. One is the availability of places like Toledo and Solerno for international concourse, where one can light a candle from a candle. Second, the interest in our own developing societies to give the topmost priority to firstly, the acquisition of knowledge and secondly, its dissemination throughout the community.

Regarding the first point, regretfully, the opportunities for international scientific concourse are fast shrinking, with greater and greater restrictions in the traditional countries like the UK and the USA on acceptance of overseas scholars, including those from developing countries. When I was a student at Cambridge, the tuition fees amounted to no more than UK £70 a year. Next year they will be UK £3,500, an increase by a factor of fifty. As I will discuss later, it is becoming clear that the developing world will need internationally-run, United Nations agency-run, postgraduate universities of science not just for research, but also for the high level teaching of modern technology and sciences, both pure and applied.

The second prerequisite for development of science and technology is a passionate, consuming desire on the part of the developing countries and the removal of all internal barriers in its acquiring dissemination of sciences and technology throughout their societies and finally, the application of these towards development. Unfortunately, and I say this with anguish, by and large, the prognosis in this respect is not very bright. We know that one of the major reasons for the dominance of the West is their near monopoly on science and technology. And yet, we in the Third World are blind. We do not take the right steps to acquire these, we do not trust our people enough to encourage them. Many of our countries wrongly feel we are too small, too resourceless to create sciences.

There are, in general, two things wrong with science in developing countries. Firstly, its sub-critical size, and secondly, that it is not part of international science. So far as physics is concerned, in 1964, the International Atomic Energy Agency (IAEA) and UNESCO took the step of pioneering the first international centre in a scientific discipline, with a view to increasing the size of high-level scientific manpower and of removing their isolation. We were initially opposed by the governments of some of the developed countries, but the developing countries solidly voted to have a centre of physics and it was created.

With UNESCO's active help, and with very generous assistance from the government of Italy, the International Centre for Theoretical Physics (ICTP) was started by the IAEA in Trieste in 1964. UNESCO joined as equal partners with IAEA in 1970. Over the 20 years that the centre has now existed, it has emphasised basic physics needed for applications--subjects like physics of materials, nuclear physics, physics of plasmas and fusion, physics of reactors, physics of solar and other conventional energy sources, geophysics, laser physics, physics of oceans and deserts, high technology physics, like microelectronics, micro-processors, biophysics, physics of fibre optics and satellite communications--this, in addition to high energy physics, quantum gravity, cosmology and mathematics.

During 1983, 2,400 physicists came to the centre--1,400 of them from 90 developing countries. These physicists spend, on the average, two months or more at the centre, participating in research workshops and extended research colleges. We have pioneered an associateship scheme which guarantees that top physicists in developing countries can come to the centre for a period ranging between six weeks to three months, three times in six years, to work in a stimulating environment of their peers, to charge their batteries and then to return to their teaching and research positions. There are 200 such associates at present (including Professor F. Onyango, the Dean and Dr. W. Ogana), most of them financed by the Swedish Agency for Research and Cooperation in Developing Countries, (SAREC), and some from a special grant from Denmark. We have a network of 88 institutes of physics in developing countries federated with us with cost sharing arrangements. The centre has meaningfully strengthened physics and physics communities in the developed and developing world.

There is no question that the Trieste Centre still is the model for future international assays in scientific collaboration. There is no question but the developing world needs today international institutions of this type, but with requisite stability, e.g. on the applied side, institutes like the Wheat and the Rice Research Institutes; on the physics side centres like that at Trieste; and on the biology side like ICIPE in Nairobi. Without internationalization science cannot flourish; one cannot guarantee standards, guarantee keeping abreast of new ideas, guarantee a transfer of science and technology by men who created it.

As I mentioned before a companion centre to the Trieste Centre is ICIPE which Africa can be proud of. The Trieste ICTP example is now being copied with the recent setting up by France, of an international centre in mathematics at Nice, and of an international science centre in Sri Lanka. A centre of physics, directly inspired by Trieste, was formally set up in Colombia last month. The new president, Professor Betancer, on taking office, has, as one of his priorities, specifically ordered that the centre's building must be completed in 12 months. And you probably know, the United Nations Industrial Development Organization (UNIDO) is on the way to creating one or more international centres in biotechnology. The decision will be taken soon whether this centre goes to Italy, Spain, Belgium, India, Pakistan, Egypt or Thailand. It may well be that seven centres are created, each specialising in a sub-discipline of biotechnology. And finally, the United Nations University is contemplating setting up a centre for economics in Finland and one for natural resources somewhere in Africa. My own feeling is that almost every developing country has a technological problem which needs international scientific expertise. The United Nations system in Kenya, UNESCO and UNEP, must take a lead with this legitimate movement towards the internationalization of science in developing countries.

In sciences, as in other spheres, this world of ours is divided between the rich and the poor. The richer half, the industrial north and the centrally managed countries, with an income of five trillion dollars, spend two percent of this--some 100 billion dollars--on non-military science and development research. The remaining half of mankind, the poorer south, with one-fifth of this income of around one trillion dollars, spend no more than two billion dollars on science and technology. On the percentage norms of the richer countries, they should be spending ten times more--some 20 billions. At the United Nations-run Vienna Conference on Science and Technology held in 1979, the poorer nations pleaded for international funds to increase their present expenditure of two billions to four billions. They obtained promises, not of two billions, not of one billion, but only one-seventh of this. Even this was not realized and the United Nations Funding System for Science and Technology for Development is without adequate funds.

But we must not forget that, in the end, the promotion of science and technology among us is the responsibility of the developing countries themselves. I wish to say this to our rulers: Our people of science are a precious asset. Prize them, give them opportunities, responsibilities for scientific and technological development of their own countries. At present, even the small numbers that exist are underutilized. However, the goal must remain to increase the two billions internally spent on science and technology to 20 billions. Science is not cheap, and in addition, we must not forget that technology in the conditions of today cannot, in the long run, flourish without science flourishing at the same time. This was dramatically emphasized recently to me by a Turkish physicist from the University of Samsun who recalled that Sultan Selim III did introduce studies of algebra, trigonometry, mechanics, ballistics and metallurgy in Turkey as long ago as 1799, creating special schools for these disciplines with French and Swedish teachers. His purpose was to modernize the army and rival European advances in gun-foundries. Since there was no corresponding emphasis on research in these subjects, Turkey did not succeed. In the long run, in the conditions of today, technology unsupported by science, simply cannot flourish.

Science Transfer and Technology Transfer

I shall illustrate through some historical, as well as recent examples, how basic scientific research impinges on modern technology. My first example is Faraday's unification of electricity and magnetism, accomplished in the last century. Before Faraday, one thought of the electric and the magnetic forces as two distinct forces with no interrelation between them. Electricity was typified by the phenomenon of thunderstorms, magnets were bar-magnets deflected by the earth's magnetism. Faraday, experimenting in his basic sciences' laboratory at the Royal Institution in London's Piccadilly, discovered an amazing interrelation between these two disparate forces. Move an electrically charged object in the vicinity of a magnet, and the magnet suffers deflection.

The conclusion of this and similar experiments was inescapable and sensational. The magnetic force is not an independent force. Electrically charged objects produce electric forces when they are stationary. They give rise to magnetic forces when moved. Electricity and magnetism had been united and unified. This was one of the greatest discoveries in physics of all times. And when Faraday was making his experiments, no one could have imagined that this simple physics discovery in a laboratory in a fashionable and dilettante part of London, would lead to the entire corpus of electrical power generation.

Just to emphasize how relatively useless Faraday's work was thought to be by his contemporaries, consider the assessment of one of them, Charles Burney, of the uses of electricity versus music: "Electricity is universally allowed to be a very entertaining and surprising phenomenon, but it has frequently been lamented that it has never yet, with much certainty, been applied to any very useful purpose...(While) it is easy to point out the humane and important purposes to which music has been applied...many an orphan is cherished by its influence, and the pangs of child-birth are softened and rendered less dangerous..."

The story of unification of electricity with magnetism, continues with Maxwell who immediately followed Faraday. Maxwell asked himself the question: Faraday has shown that moving electric charges produce magnetic forces. What would happen if electric charges were accelerated rather than moved with uniform velocity? Maxwell pondered theoretically on this question. He found Faraday's equations were inconsistent--they had to be modified if electric charges were accelerating. By one of the greatest acts of intuition in intellectual history, he supplied the correct modification and discovered, to his amazement, that an accelerating electrically charged object must emit electromagnetic radiation. He could compute the velocity of this radiation. Again to his surprise, this velocity turned out to be identical to the velocity of light, then known with fair precision from experiment. Could light be electro-magnetic radiation, produced by accelerating electrical charges embedded inside incandescent matter? Could we accelerate electrically charged particles in the laboratory and produce light? Could we verify Maxwell's theory directly in the laboratory?

A few years after Maxwell's death in 1879, Hertz in Germany, carried out such experiments with accelerating electric charges. Every one of Maxwell's predictions was found correct. The spectrum of Maxwell's predicted radiation consisted, not only of light waves, but also, of waves of longer wave length--radio waves--as well as waves of shorter wave length--X-rays. Thus, from a single theoretical calculation done by an obscure professor at the Cavendish Laboratory--a laboratory endowed not by the state, but by a private individual, Lord Cavendish and his family--flowed the marvels of radio, television and the modern communication systems, on the one hand, as well as the medical facility to see through a human body with X-rays. These discoveries, we in the Third World employ in our service along with the rest of mankind, hardly acknowledging the debt humanity owes to that modest physicist, Maxwell, and his solitary calculations. Maxwell's hundredth anniversary fell due in 1979; some six men from the University of Glasgow congregated at his grave and that was all the homage the world paid him.

My next example is fission. This is the breaking apart of a heavy overweight nucleus, such as uranium, into two or more fragments, when impacted by a slow-moving projectile like a thermal neutron. No one was looking for it--no one suspected it. The great Italian physicist Fermi, working in the dingy laboratories of the department of physics at the University of Rome, could have found these fission fragments in the debris deposited in his test tube for they were there. But he was not looking for such fragments and missed them. The phenomenon was rediscovered in Germany at the Kaiser Wilhelm Institute for basic sciences in December 1938--not by physicists but by two nuclear chemists, Hahn and Strasseman. In their paper, the authors said, "As nuclear chemists who are close to physicists, we are reluctant to take this step that contradicts all previous experiences of nuclear physics."

With this humble announcement began the age of nuclear energy for peace and for war. The equipment, the apparatus used, was so simple, even a humble laboratory in a poor

Third World country could have afforded it. Today, in the context of nuclear energy, European, American, Russian, Japanese and Chinese laboratories are experimenting with the phenomenon of fusion--the taming of the energy release in a hydrogen explosion. These are at present laboratory experiments; as yet not commercial technology. The European nations have together created a joint laboratory--JET--at Culham in the UK. The UN Agency, IAEA, is projecting a joint device for the world; to my knowledge no Third World nation has yet asked to join this project. With Russian help, Libya has had the foresight to set up a small Tokamak device in Tripoli for experimentation in this field, but has not yet created the modalities through which teams of experimenters from Arab-Islamic and African countries could come and use this device.

My next example is in the area of biotechnology. As is well known, the modern advances in genetics started with the unravelling of the genetic code by Watson and Crick. In the synthesis it has provided in giving the basis for all known life, this has been one of the most synthesising discoveries of the 20th century, possibly of all times.

This great discovery in biology was made at Cambridge in April 1953, by two scientists--one American, the other British--working at the Cavendish Laboratory for basic physics. Walter Gilbert, a theoretical physicist with whom I worked on dispersion phenomena, was a neighbour of the genetic code's American co-discoverer, J. D. Watson, in Cambridge. Gilbert and Watson went to Harvard in 1956. I saw Gilbert in 1961 in the US. Assuming that he was still working on some problem on the theoretical physics, I asked him what he was up to. He was somewhat sheepish. He said, "I am sorry, you will be ashamed of me. I am spending my time growing bacteria." Watson had seduced him for genetics. Gilbert soon discovered a most elegant technique for deciphering the genetic code. For this work, he received the Nobel Prize in Chemistry in 1980. In 1981 he left his chair at Harvard to found a company which exploits, among others, techniques of genetic manipulation to manufacture human insulin. This company is called Biogen and is registered in Switzerland. It went public recently. Apparently, Gilbert's first investment in the company (of which he is President) was of US $4,000. This is currently worth more than 14 million dollars.

Notice the mutuality of science and technology. Notice that the greatest discovery in molecular biology is made in a laboratory for physics, by men trained in the use of X-rays with fairly modest equipment. Notice Gilbert's transition from research in theoretical physics to fundamental genetics and then to practical genetic engineering. The point I am trying to make is twofold. First, science and technology go hand in hand in modern times. Second there is a premium placed on excellence and brain power in our rival civilizations. We must ask ourselves: do we provide like opportunities for our best young men and women nurturing their talents for our civilization, or do we leave them to wither away, or if they are strongly committed to science, to migrate and enrich the countries of Europe and America with their talents and their contributions?

Perhaps my examples appear too distant for comfort, though the biotechnological example is not all that far-fetched. Perhaps the intervening centuries of neglect of sciences have lured into us a feeling that we can never catch up in the creation of sciences, and that we need not even try. I started in my first example with Faraday's and Maxwell's unification of two of the fundamental forces of nature--of electricity with magnetism--in the last century. I said, from this unification flowered the age of electric power and next, the age of wireless communications. When a hundred years after Maxwell, in the nineteen-sixties, my colleagues at Harvard, Glasbow and Weinberg, and myself independently took the next step of postulating a unification of two further forces of nature--of electromagnetism with the weak nuclear force of radioactivity--even the London *Economist* took note and counselled perceptive businessmen not to ignore the likely economic consequences of this new unification.

Our theory had been indirectly confirmed through its consequences for diverse phenomena in nuclear and atomic physics by 1978. This year, in January, the great joint European experimental laboratory at Geneva provided the direct confimation of our theory. We had predicted the existence of three mediators of the weak nuclear force W^+, W^-, and Z^os. We had specified their expected masses as a consequence of the unification. The January experiment showed that W^+ and W^- indeed do exist, with precisely the predicted masses. This week the last particle, the Z^o, has also been identified among the products of the collisions of protons and anti-protons in the 6 km accelerator of CERN (Centre Européen de Recherche Nucléaire). To obtain a beam of anti-protons, the laboratory had to invent a new principle of "stochastic cooling" of anti-protons and to execute this idea with a technical brilliance of the highest order at a cost of around 50 million dollars. This same laboratory is now engaged in building a new accelerator of 27 kms circumference under the Jura mountains of Geneva for further experimentation with our theory. This will cost them half a billion dollars and will be completed by 1987.

A Third World journal published from London has sagely counselled that we in developing countries should not concern ourselves with advances in science. We should concentrate on imitative technology, assuming someone will sell it to us. This is what the Japanese are supposed to have done. We forget that the Japanese have already won four Nobel Prizes in science--three in physics and one in chemistry. Their base in fundamental sciences is as strong, or in some cases, stronger than in the west. We forget that it was this unspoken and unsung base on which they have built their innovative successes in technology. We forget that an accelerator like the one at CERN, develops sophisticated modern technology at its furthest limit. I am not advocating that we should build a CERN for Third World countries. However, I cannot feel but envious that a relatively poor country like Greece has joined CERN, paying a subscription according to the standard GNP (Gross National Product) formula. I cannot rejoice that Turkey, or the Gulf countries, or African countries, or my country, Pakistan, seem to show no ambition to join this font of science and get their scientific men and women catapulted into the forefront of the latest technological expertise.

Working with CERN accelerators brings at the least this reward to a nation, as Greece has had the perception to realise.

Let me close this part of my discussion about the interrelation of science and technology with an example, nearer home, from the field of solar energy. This is a field where research is being carried out by African and Middle Eastern universities. The basic problems with the development of cheaper photovoltaic devices, are material sciences problems. Solar energy is collected, and converted by materials that are optically or photoelectrically suitable. An optical convertor must use as little material as possible. How little is determined by the penetration depth of the solar light, and the drift-length of the "excited state" on which the conversion is based. One can easily determine that the parameters entering these basic processes lead to thicknesses of material of the order of one micrometer. This then is the domain of thin films. Such films are cheap to make, but there is no way to make them with the perfection of a single crystal. Thin films are polycrystalline or amorphous. And they carry a large density of defects. Up to now it is these defects which have limited the thin film devices to low conversion efficiencies. Thus, before any technological amelioration can come, one must solve the problems of basic solid state physics, of classifying the major defect phenomena, their effect on electron dynamics and problems of catalysis of the growth mechanism that makes these defects harmless.

What I am saying is that efficient photovoltaics do not depend on the engineers' tinkering with solid state materials. The problem is one of solid state physics. And it is this problem of basic science which the Japanese solid state physicists have set themselves to solve systematically, before their counterparts in the USA or Europe. The Japanese will win this prize, not only because they are the more meticulous technologists, but also because they are the systematic physicists, with scientific facilities which, in many cases, are superior to what their rivals possess. The point I am making is that what we will need, if we wish in the long run to develop first rate research on photovoltaics, is basic physics surface laboratories, basic knowledge of materials physics, in addition to technological support. The same sentiment was endorsed by the London *Economist* which, in its issue of 27 September, 1980, has this to say on the cherished mastery of solar energy: "If solar energy is to provide the solution to the world's fuel crisis, that solution will not emerge from low-technology roof-top radiators--(which) rely on 19th century (science). A breakthrough (will) come from applying quantum physics, bio-chemistry, or other sciences of the twentieth century". Today's technology-based industries all depend on new science.

And one other aspect of science transfer versus technology transfer is the broad front on which science has to be available if we wish to make use of it for technology. Steven Dedijer has given an example which appears below:

RAW MATERIAL RESEARCH

Analytic Chemistry	Organic Chemistry	Ultrastructure
I. Detection and elimination of harmful factors	II. Effect of technological process of nutrients	III. Nutritional and sensory evaluation of food formulas
Clinical Chemistry	Physics	Technological Mathematics
Alimentary Sciences	Ultrastructure	Sensorial Metrology
Toxicology	Alimentary Sciences	Experimental Medicine
Nutrition and Metabolism Physiology	Organic Technology	Physiology Nutrition and Metabolism

Dedijer explained that the table was translated from a 1981 Nestlé pamphlet:

> [It] illustrates the strategic advantage the industrialized countries have in all technology transfers over the other countries. The table shows all the basic and applied sciences Nestlé uses to develop, from the soya bean plant, a series of products, processes and production units. The brochure then shows how these products, processes, factories are "transferred" among others, to the South. The scientific base--the know-why, know-how, know-who of science--is not transferred. It remains "at home" as a foundation for newer, better industrial outputs.
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> The scientific base of all products and processes, is becoming stronger. The more science a new product or process has, the more it is liable to be competitive. Most Third World countries have hardly any creative science. Ninety percent of world research potential is concentrated in about 35 countries with about 25 percent of world population. Hence the imperative for a Third World country to find the most effective policy to bring about rapidly a macro science transfer on which to base its development. Without such a science transfer a Third World country will continue

to be technologically, and hence economically and politically, one-sided dependent, more simply said, exploited in its international exchanges.

I hope I have convinced you that in the conditions of today there can be no high technology without good science on a broad front. Make no mistake, I am not advocating that developing countries should neglect emphasis on research in areas of strength--agriculture, flora, fauna and natural resources. Clearly these areas constitute the very first priorities for development. But in addition, I am advocating that there are areas of high technology based on high science which must also be developed by all Third World countries of comparable size and ambition.

STEPS NEEDED TO EXCELL IN SCIENCES

Whether it is in areas of natural resources, or in areas of the newer technologies, how can we turn the pages of history back, and excel in science and technology? First and foremost, there is need for scientific literacy, hard scientific education to nearly half of our people followed by a provision for a career in sciences. And so far as scientific research is concerned, we must also, like the developed world, pursue basic and applied sciences, with one-two percent of our GNP spent on research and development, with at least one third of this on pure sciences.

This was done in the USSR in spite of their inferior GNP when they started. This was done in Japan, after the 19th Century Meiji revolution, with the pledge from the Emperor to seek and acquire scientific knowledge from wherever it could be acquired. And this is what is being undertaken today--in a planned manner, at a frantic speed--by the People's Republic of China, with defined targets in space sciences, genetics, microelectronics, high energy physics, agriculture, and in the control of thermonuclear energy. There is a clear recognition in these societies that basic science is relevant science, that the frontier of today is tomorrow's application and that one must remain at the frontier. They have realised that there is only one path to gaining ascendancy in science and technology--master science as a whole.

Earlier, I spoke of patronage for the sciences. One vital aspect of this is the sense of security and continuity that scientists-scholars must be accorded for their work. Like all human beings, scientists or technologists can only give of their best if they know they will have security, respect and equality of opportunity for their work, and are shielded from all forms of discrimination, sectarian and political.

To summarize the general principles, the renaissance of the sciences within the Third World is contingent upon five cardinal preconditions: passionate commitment, generous patronage, provision of security, absence of discrimination, and self-governance and internationalization of our scientific enterprise. Let me conclude by remarking once again that in today's conditions, science and technology is the main concern of every developing country, just as food, health, or education is. We must be ambitious, our men and women are in no sense inferior to any elsewhere. We must not fail to provide adequately for science and technology. We must stop thinking that we should not engage in the newer science-based technologies and that we should not be creating the relevant science as others do.