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PHYSICS AND DEVELOPMENT

Spring College on Amorphous Solids and the Liquid State

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F O R E W O R D

Due to the intense scientific programmes of the Centre, every year a large number of scientists from all over the world, and in particular from the Developing Countries, come to the Centre participating in various activities mainly in Physics and Mathematics.

It was decided to take advantage of this situation and to start a regular programme aimed at making our guest physicists and mathematicians conscious of how Physics and Mathematics are relevant to the development of their countries.

In this content some outstanding experts in the subject will be invited to give lectures. In addition some participants of each activity at the Centre are asked to give a talk on this subject with particular reference to their own countries. These talks will then be issued regularly after each ICTP activity in the form of an internal report.

The present report contains the lectures delivered by the participants of the Spring College on Amorphous Solids and the Liquid State.

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L I S T O F C O N T E N T S

THE ISOLATION OF THE SCIENTIST IN DEVELOPING COUNTRIES

ABDUS SALAM

Metropolis and Province in the Scientific World

Five hundred years ago—around 1470 A.D.—Saif-ud-din Salman, a young astronomer from Kandhar, working then at the celebrated observatory of Ulugh Beg at Samarkand, wrote an anguished letter to his father. In eloquent words Salman recounted the dilemmas, the heart-breaks, of an advanced research career in a poor, developing country:

"Admonish me not, my beloved father, for forsaking you thus in your old age and sojourning here at Samarkand. It's not that I covet the musk-melons and the grapes and the pomegranates of Samarkand; it's not the shade of the orchards on the banks of Zar-Afshan that keeps me here. I love my native Kandhar and its tree-lined avenues even more and I pine to return. But forgive me, my exalted father, for my passion for knowledge. In Kandhar there are no scholars, no libraries, no quadrants, no astrolabes. My star-gazing excites nothing but ridicule and scorn. My countrymen care more for the glitter of the sword than for the quill of the scholar. In my own town I am a sad, a pathetic misfit.

"It is true, my respected father, so far from home men do not rise from their seats to pay me homage when I ride into the bazaar. But some day soon all Samarkand will rise in respect when your son will emulate Biruni and Tusi in learning and you too will feel proud."

Saif-ud-din Salman never did attain the greatness of his masters, Biruni and Tusi, in astronomy. But this cry from his heart has an aptness for our present times. For Samarkand of 1470 read Berkeley or Cambridge; for quadrants read high-energy accelerators; for Kandhar read Delhi or Lahore and we have the situation of advanced scientific research and its dilemmas in the developing world of today as seen by those who feel in themselves that they could, given the opportunity, make a fundamental contribution to knowledge.

But there is one profound change from 1470. Whereas the emirate of Kandhar did not have a conscious policy for the development of science and technology—it boasted of no ministers for science, it had no councils for scientific research—the present-day governments of most developing countries would like to foster, if they could, scientific research, even advanced scientific research. Unfortunately, research is costly. Most countries do not yet feel that it carries a high priority among competing claims for their resources. Not even indigenous *applied* research can command priority over straightforward projects for development. The feeling among administrators—perhaps rightly—is that it is by and large cheaper and perhaps more reliable to buy applied science on the world market. The resultant picture, so far as advanced research is concerned, remains in practice almost as bleak as at Kandhar.

Why Advanced Research Lags in Underdeveloped Countries

First and foremost among the factors that affect advanced scientific research is the supply of towering individuals, the tribal leaders, around whom great institutes are built. These are perhaps 2–3 per cent. of all men who are trained for research. What is being done in the underdeveloped world to ensure their supply? Most developing countries are doing practically nothing. Quite the contrary, with all the obstacles and hazards which beset a poor society, it is almost miraculous that any talent at all is saved for science. These hazards are, first, the very poor quality of education; second, the higher or administrative grades of the civil service—in India, the Indian administration service, and in Pakistan, its analogue, the civil service of Pakistan—which skim off the very top of the sub-continent's intellect; third, the poor chances for a promising young research student to learn to do research as an apprentice to a master scientist. The greatest obstacle of all lies in the very low probability of having the opportunity to work with the few men—in the case of India and Pakistan, the Siddiquis, the Usmanis, the Menons, the Sarabhais, the Seshachars—at the few centres of excellence, who appreciate at all the demands of a research career and who run laboratories which are reasonably well equipped. There are just too few scientists who retain the creativity of which they gave promise when young and there are therefore too few to train younger scientists through a fruitful master-apprentice relationship. It remains a sad fact that, though India and Pakistan may have built specialised institutes outside the university system where advanced research is carried out, by and large their vast university systems remain weak, static and uninspired. It is not part of their tradition to make a place for advanced research or even for research at all. The colleges which provide a very large proportion of undergraduate education in India and Pakistan have grown up in a tradition of concentrating such resources as they have on the instruction and moral formation of undergraduates. I shall always remember my first interview with the head of the premier college in Pakistan, which I joined after a spell of theoretical work in high-energy physics at Cambridge and Princeton. My chief said: "We all want research men here, but never forget we are looking more for good, honest teachers and good honest college men. This college has proud traditions to uphold. We must all help.

Now for any spare time you may have after your teaching duties, I can offer you a choice of three college jobs: you can take on wardenship of the college hostel; or be chief treasurer of its accounts; or if you like, become president of its football club". As it was, I was fortunate to get the football club.

Admittedly, this was 12 years ago. I should be ungrateful if I did not mention that this same college today is contending with the Atomic Energy Commission of Pakistan for the control of a high-tension laboratory with a 2·5 Mev Cockcroft-Walton set. This is a measure of the change brought about by the heroic efforts of the Pakistan Government since 1958. Things have changed. Nonetheless the situation of advanced research in underdeveloped countries still remains greatly in need of help.

In a number of fields, advanced scientific research in developing countries is beginning to reach the stage of maturity in which first-rate work can be done. Indigenous resources are being skilfully employed but there is still a desperate need for international help. The truth is that, irrespective of a man's talent, there are in science, as in other spheres, the classes of haves and have-nots; those who enjoy the physical facilities and the personal stimulus for the furtherance of their work, and those who do not, depending on which part of the world they live in. This distinction must go. The time has come when the international community of scientists should begin to recognise its direct moral responsibility, its direct involvement, its direct participation in advanced science in developing countries, not only through helping to organise institutions but by providing the personal face-to-face stimulation necessary for the first-rate individual working in these countries.

In advanced scientific research, it is the personal element that counts much more than the institutional. If, through meaningful international action, allied with national action, we could build the morale of the active research worker and persuade him not to make himself an exile, we shall have won a real battle for the establishment of a creative scientific life in the developing countries.

Breaking the Barrier of Isolation

As an example of what is needed, I shall take the science with which I am personally associated. Theoretical physics happens to be one of the few scientific disciplines which, together with mathematics, is ideally suited to development in a developing country. The reason is that no costly equipment is involved. It is inevitably one of the first sciences to be developed at the highest possible level; this was the case in Japan, in India, in Pakistan, in Brazil, in Lebanon, in Turkey, in Korea, in Argentina. Gifted men from these countries work in advanced centres in the West or the Soviet Union. They then go back to build their own indigenous schools. In the past, when these men went back to the universities in their home countries, they were perhaps completely alone; the groups of which they formed a part were too small to form a critical mass; there were no good libraries, there was no communication with groups abroad. There was no criticism of what they were doing; new ideas reached them too slowly; their work fell back within the grooves of what they were doing before they left the stimulating environments of the institutions at which they had studied in the West or the Soviet Union. These men were isolated, and isolation in theoretical physics—as in most fields of intellectual work—is death. This was the pattern when I became associated with Lahore University; this is still the pattern in Chile, in Argentina, in Korea.

In India and Pakistan we have been more fortunate than most other underdeveloped countries in the last decade. A number of specialised institutes have grown up for advanced work in theoretical physics—the Tata Institute at Bombay, the Institute of Mathematical Sciences at Madras and the Atomic Energy Centres at Lahore and Dacca—where a fair concentration of good men exists. But this is not enough. These institutes are still small oases. They are too small for the fertilisation of the area around them. They are also in continuous danger of being dried up because the area around them is too arid and they still do not have vigorous contacts with the world community. Tata and Madras have partly solved their problem; they have funds to invite visitors—they have fewer funds to send Indian physicists abroad, mainly because of the serious shortage of foreign exchange.

It was with this type of problem in mind that the idea of setting up an International Centre for Theoretical Physics [1] was mooted in 1960. The idea was to establish a truly international centre, run by the United Nations family of organisations, for advanced research in theoretical physics. It was planned with two objectives in view: first, to bring physicists from the East and the West together; second, and even more important, to provide extremely liberal facilities for senior active physicists from developing countries.

The International Centre tries to deal with the problem of isolation in a number of ways. We have ordinary fellowships which are given mostly to those from developing countries. In addition, the International Centre has instituted an associateship scheme. A number of carefully selected senior active physicists from developing countries are given the privilege of coming for a period of one to four months every year to the centre with no prior formalities other than a letter to the director announcing

[1] *Cf.*, *Minerva*, III, 4 (Summer, 1965), pp. 533-536.

their arrival. The centre pays for their transportation and their maintenance. The aim is to have eventually, at any one time, a group of about 50 senior active physicists from developing countries who possess this privilege.

Looking back on my own period of work in Lahore, as I said, I felt terribly isolated. If at that time someone had said to me, we shall give you the opportunity every year to travel to an active centre in Europe or the United States for three months of your vacation to work with your peers; would you then be happy to stay the remaining nine months at Lahore, I would have said yes. No one made the offer. I felt then and I feel now that this is one way of halting the brain drain, of keeping active men happy and contented within their own countries. They must be kept there to build for the future, but their scientific integrity must also be preserved. By providing them with this guaranteed opportunity for remaining in contact with their peers, we believe we are making a contribution to solving the problem of isolation.

Ideally the associateship scheme should be wide enough to cover nearly every active physicist in developing countries. It should be well publicised; every first-rate research worker should know and feel confident that he could almost, as it were, demand its privileges if he were living in a developing country. Unfortunately, the International Centre at Trieste does not possess funds to do this. Yet the scheme is not very costly. Since it pays no salaries—only the fare and a *per diem* allowance—it costs us something like $100,000. Since the associateship scheme seems thus far to be the most fruitful of all the available ways for breaking the isolation which kills the creativity of creative scientists, it should be extended.

Universities and institutions with the wealth and scientific eminence of Princeton, Harvard, Cambridge, All Souls, Rockefeller University, New York State University, the Imperial College in London and others should seriously consider the establishment of their own associateship schemes. It ought to be considered not only for theoretical physics but for other subjects too. Rockefeller University, for example, might extend the privilege of giving its freedom not only to a scientist of the distinction of Professor Seshchar, but also to other active micro-biologists in most developing countries. The European Organisation for Nuclear Research at Geneva has already started a scheme similar to our own, which, I believe, covers both experimental and theoretical physics. It is designed of course only for less-developed countries within Europe (Greece and Spain).

If every active, first-rate worker in the developing countries could be covered, we would go very far towards the removal of one of the curses of being a scientist in a developing land.

INDIA

TRENDS IN MATERIALS SCIENCE AND DEVELOPING COUNTRIES

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I. INTRODUCTION

Since the early ages of civilization much thought and action have gone into procuring, creating and using the materials. In modern society, materials science has become an important branch of science to create the materials. This science provides strong interaction between basic research and applications, bridges the gap between sciences and engineering and has the capacity of fulfilling many social expectations.

In every sphere there are trends at a given time whether they are clothing, housing, etc., or scientific disciplines. Knowledge of the trends is vital in order to remain on the forefront. It also provides stimulus to tailor mould the future trends and actions.

In this article, the author summarizes the current trends in basic researches in materials science [1-8]. Then social demands from material scientists are mentioned. Suggestions for the trends which could be set in the developing countries (DCs) by the basic researchers to meet social demands are discussed. The priorities that could be set in view of resource constraints in DCs compared to the advanced countries (ACs) are mentioned.

II. TRENDS IN MATERIALS SCIENCE

Material researchers concentrate on aspects listed in Table I. It is obvious that the trends have been fairly wide spread. This is not surprising in view of the historic role of materials (role of polythene and ferrites in World War II is fairly known).

As recently pointed out by Laudise [4] the properly guided materials science can play a major role in problem solving. It can also fulfill the major social demands as mentioned in the next section.

In the author's opinion, the trends that could be followed in DCs should be based upon:

a) systematic thinking before deciding priorities for topics;
b) Adequate development of human endowed with highest talents and necessary attitudes;
c) Infrastructure to bring the fruits of basic researches into engineering and social requirements as basic researches in materials sciences has greatest potential for this;
d) Excellent centre in at least one particular topic in which there is no phase lag or aptitude lag between DC and ACs.

Table I

Different trends in materials science research

1. Preparation and processing
   a) crystal growths
   b) thin film and epitaxial growths
   c) memory, imaging, sensing devices
   d) powder, metallurgy, curing, welding, adhesion, etc.

2. Characterization of materials
   a) structural studies
   b) spectroscopic studies.

3. Properties and special phemomenon like integrated optics, pico and femtosecond spectroscopy, molecular geology, Josephson devices. Soft modes and charge density wave devices, memories, optical communication and electron-hole droplets.

4. Radiation effects and damages.

5. Special materials

	Group	Distinguished member of the group
①	III-V and II-VI semiconductors	$Ga\ As_{1-x}\ P_x$
②	Photoconducting materials	Sb(S,I)
	magnetic bubble	$Lu_{0.34}\ Y_{1.44}\ Sm_{0.28}\ Ca_{0.94}\ Fe_{4.06}\ Ge_{0.94}\ O_{12}$
③	Permanent magnets Re-Co alloys	$Co_{3.3}\ Cu_{1.2}\ Fe_{0.5}\ Ce_{0.25}\ Sm_{0.75}$
④	Metallic glasses	$Fe_{40}\ Ni_{40}\ P_{14}\ B_6$
⑤	Spinodal high strength alloys	Cu-Ni-Sn
⑥	Low cost solar cell materials	$a\text{-}SiH_x$
⑦	Liquid crystals	MBBA
⑧	Organic crystal of metallic conductivity	HMTSF-TCNQ
⑨	Superionic conductors and solid electrolytes	$Rb\ Ag_4\ I_5$
⑩	High T_c superconductors	$Nb_x\ Ge_y$
⑪	Tip tool hard materials	$W_x\ C_{1.x}$
⑫	Glasses	Glass fibre reinforced plastics

Fig.1 shows the path that could be followed to decide the trends needed to be set in a DC.

III. SOCIAL DEMANDS AND MATERIAL SCIENTISTS

Table II lists the social demands of various sectors.

Energy is most efficient use of materials. So naturally this should be and is the area of high priority for basic researchers. Oil deficient DCs cannot neglect this aspect. Some recent developments in one of the oil deficient DC (India) can set new trends in materials research. These are development and putting in actual use the rice husk based boilers, the utilization of biogas from dung and wastes, etc.

Cheap housing is another important social demand in DCs. The easiest way in which material scientists can help is by creating a new material substitution strategy based upon coatings, sputtering, ion-beam implantation. Direct substitution or frugal design could be made. One new trend in India in this direction is rice husk based cements.

Similarly, new trends could emerge in DCs in areas like health, communication, transport, etc. The author would like to emphasise demands of the material resources management. This demand is becoming a global one and obviously due to resources constraints will have a greater impact on DCs than ACs. Though the mass of earth itself is 6.5×10^{24} Kg, most of it is unusable at present. The most abundant in the earth's crust is silicon. Fortunately, the semiconductor electronics revolution is based on silicon. So centers for researches in silicon could be first the researchers proprity in the DC. Next in abundance come Al, Ca, Fe, Mg, K and the rest constitutes less than 1/2 percent. Further, as only high grade ores could only be used at present due to economic reasons, the availability of this rest is increasingly threatened. Geographical imbalances in distribution further aggrevates the availability for many DCs. Hence, research programme has to be so oriented as there is increasily full or partial replacement of the rest of the elements by easily available ones, e.g. material science reasearches on tin and tin based elements could be of high priority in Malaysia, Thailand, etc. Replacement of costly gold contacts by other alloys, development of spinodal alloys, lifetime extension of polythene, Al and Al-based alloys as conductors, as engineering materials and use of ion implanation are few examples where vital contributions were made by basic researchers in the recent past. New trends should emerge in coming years as the pressure of this demand will increase.

Table II

Different social demands and material sciences research

	Social demands	Material sciences research
1	Energy	Materials for non-conventional energy sources
2	Cheap housing	Substitutes for cement, steal and glasses, frugal design strategy and materials substitution techniques
3	Health	X-rays, photographic materials, pharmaceutical
4	Communication	IV, II-VI, III-V semiconductors, ferrites, quartz, sensors and LEDs
5	Transport	Steel, glass
6	Material resources Management	Lifetime extension, recycling, function, direct and frugal substitution and special materials development
7	Space and aerospace	Fibre composites, high temperature materials, materials of high strength per unit mass
8	Pollution	Catalyst and chemical reactants, corrosion resistants, detectors
9	Textiles	Polymers, dyes

IV. COUPLING BETWEEN MATERIAL SCIENCES AND ENGINEERING

Quoting Chynoweth [6], "materials and their uses do not recognize disciplinary demarcation lines, they provide a natural ground for collaboration between disciplines". The article also lists some selected topics of basic research and examples of engineering applications. In addition, the basic researches on the characterization of solids by microscopical, stereological, spectroscopical and mechanical techniques is an important aspect for engineering too.

There is a high degree of awareness in ACs and Dcs about the need for this coupling. However this coupling is too weak in DCs. The author will illustrate the above with a few examples he is aware of. A razor blade company was in need of suitable coating on razor blades to improve its products. The company was situated within 50 km of a leading basic research centre in thin films and their properties. It took several years to approach this centre and that too when it was routed through company's associates in an AC. An automobile tractor spare part manufacturing unit purchased atomic X-ray fluoroscence spectrometers, electron microscopes, etc. at the cost of more than 1 million US $. It recovered 50% of the amount from the Government as tax rebate and the balance from publicity for having such facilities. Neither did it actually employ trained personnel nor thrown open such facilities of basic researchers in its vicinities to make utilization of such excellent facilities.

V. SUGGESTIONS FOR EFFECTIVE COUPLING

In one of the leading Swedish Universities, Uppsala, the author became aware of the idea of "contact secretariat" within the university To this secretariat, the industry can contact for its requirements and the scientists can contact for industrial exploitation or facilities. Fine examples are (i) development of battery operated two wheeler transport, ii) microwave potato cooker, iii) computer controlled operations for few industries and iv) plastic bicycles This idea could be implemented in DCs to bring the fruits of basic researchers in material science to the engineering. It is worth pointing out here that such a secretariat needs a man with a missionary zeal.

Another suggestion is based on the recent attempts made in India. This is for creation of sphosticated regional instrumentation centres and computer centres where the university teachers, laboratory scientists and engineers from industries share the times on normal payments.

Setting up of national centres for each i) metallurgy, ii) glass ceramics, iii) silk, fibres, iv) leather, v) electronic materials including photoroltaics, vi) forest products are important steps made in India to set the trend towards the effective coupling.

V. CONCLUSIONS

Various trends in materials researches are briefly discussed. The guided materials science with special emphasis on material substitution strategy is advocated even for basic researchers. It is suggested that some dedicated human efforts can set new trends in DCs at little expense. It is the availability of adequate human resources of the right talent working in the right circumstances with the right attitudes which can set the new trends in materials science research in DCs.

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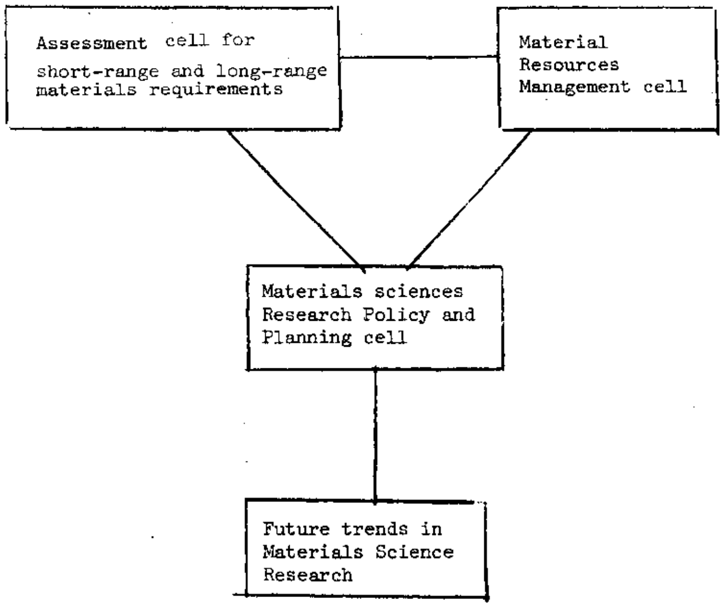
Fig. 1



Path that could be followed to decide about the trends in a DC.

I N D I A

SCIENCE AND DEVELOPMENT

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I. Parameters

II. Science → Development (past)

III. Science → Development (present)

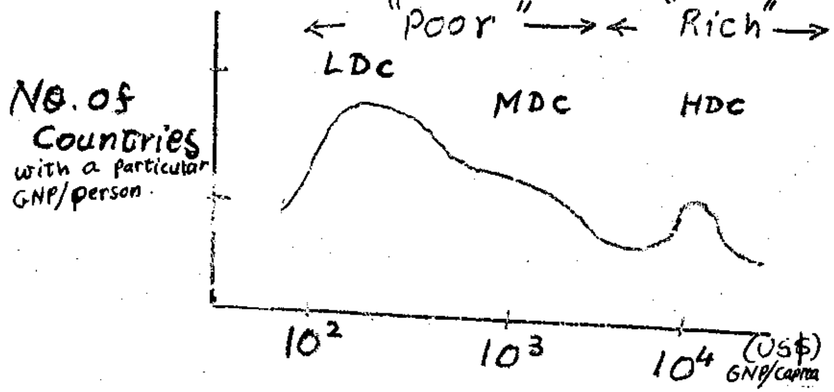
IV. A Case for Science

(Any views expressed are those of a private individual.)

I. PARAMETERS

A visiting Martian, seeing our planet for the first time, would be struck by one great division of the human race: a clear distinction between the rich and poor areas of the world. He would see (with a sharpness that, for us, is dulled by familiarity), the curtain that exists between two parts of the planet. Not an 'iron curtain' that blocks off all contact, but, on the contrary, a transparent 'plate-glass curtain', as in a shop window. On the one side, ragged and sweaty urchins, noses pressed against the glass. On the other, more fortunate children happily playing with their fancy toys in air-conditioned comfort.

Our hypothetical Martian, if suitably industrious, might locate a copy of the World Bank Development Report 1981, and from the statistics contained therein, plot a histogram of the number of countries with a given per capita GNP range, versus per capita GNP. Schematically he would get something like this:



The vertical scale is not significant here, as the present speaker is much less industrious than the Martian, the total number of countries being $\sim 10^2$. The important point is that to represent the income levels on our planet, a logarithmic scale has to be used, as the numbers vary over two orders of magnitude. The highly developed countries (HDC) in the bump on the right, (GNP/person $\gtrsim$ \$4000) would include US, Canada, Britain, France, Germany, Australia, Saudi Arabia, Kuwait(?) etc. The countries in the middle region that we somewhat ungrammatically label as MDC's, medium-developed countries, (500 $\gtrsim$ GNP/person $\gtrsim$ \$ 370) include Taiwan, Singapore, South Korea, Brazil, etc. And the group near the origin of less developed countries, LDC's, (\$370 $\gtrsim$ GNP/person $>$ 0) would include countries like India, Pakistan, Indonesia, Etc.

There has been a continuous evolution in the terminology used by economists and political leaders to describe this situation. (There has been less change in the situation itself). First we were "backward" then "poor" then "developing" and now our problems are solved by the "LDC" acronym. We have also been called "Third World" countries in some numerical classification scheme and nations of "the South" in a geographical grouping. Although in this last case, somewhat confusingly, Australia and New Zealand are nations of "the North." (The status of the penguins of Antartica is also unclear.)

Whatever the terminology the distinction between the "rich" and "poor" nations is clearly a useful one, on an average or 'thermodynamic' level. The differences between the three groups persist if we look at other parameters that define the phase diagram.

per capita GNP, US$ →

Grouping	GNP per cap. 1960	GNP per cap. 1980	Life expect. 1960	Life expect. 1980	Literacy % 1960	Literacy % 1976
HDC	5580	10,660	70	74	97	99
MDC	820	1,580	53	61	53	72
LDC	180	250	42	51	28	39

(1980$)

* * * * * * * *

Notice that although improvements have been made, the differences have persisted.

Note: Financial comparisons have been made with currency exchange rates which may not reflect the true relative purchasing power of an individual. The World Bank has set up an "International Comparison Project", with price ratios set up for 150 GNP expenditure categories of 34 countries, compared with the US. The net effect is that the GNP in \$ of the poorer countries is raised:

	Per capita GNP Currency (1980$) conversion	Per capita GNP Purchasing power (1980$) conversion
HDC	10,660	8960
MDC	1710	2690
LDC	220	730

* * * * * * * *

The above was 'thermodynamics' dealing with averages over many countries. Now let us look at a few more detailed statistics – 'statistical mechanics' (see next page).

It is not as confusing as it looks. There is a pattern. GNP: India and Indonesia with $190 and $370, respectively, bracket the LDC mean of $230, i.e. O($100). The MDC's have an order of magnitude greater O($1000) while the HDC's cluster about their average O($10,000). Life expectancy: India and Indonesia are almost the same, ~50 despite the difference in GNP/person. MDC ~60s, HDC ~70s. Adult literacy: This is where the differences are starkest. Once again India and Indonesia bracket the LDC average of 50% , Malaysia and Tunisia are somewhat less than the MDC average of about 70%. But there is virtually no spread in the literacy rate of the HDCs – it is a delta function, centred at 99%. Since literacy is a necessary (but not sufficient) condition for doing science or any tecnical work then this could be a major bottleneck for the development of an LDC, assuming a connection between science and development. Energy consumption/person: The differences in the productive power of the economic steam engines of the three groups can be seen from the per capita energy consumption (in kilogram of coal equivalents). The MDC's are a factor of 3 more than the LDCs; the HDC's a factor of 20(!) Structure of the economy: The last three columns tell us that the LDCs have a predominantly (~ 70%) agricultural work force; the problem of feeding the nation in an HDC is handled by only ~10%, releasing the rest for manufacturing,services. The MDCs are making the transitions.

So much for statistical mechanics. Some comments on one particular (macro) molecule, India. Although it falls into the category of an LDC by virtue of the parameters considered, it has certain unique features, largely due to its diversity and size. Diversity: India has ≈15 major language groups, often with different scripts and ≈ 5 of the worlds religions. Also, we Indians come in a wide variety of shapes, colours and sizes. Size: A population of ≈ 6×10^8, spread over a country the size of Europe. Economic orders of magnitude (modulo factors) are:

Country	Pop. ($\times 10^6$)	Area ($\times 10^3$ km²)	GNP (1980$)	Life Expect. (years)	Adult Literacy (%)	Energy per cap. (Kilo. coal)	% of Labour Force in Agric.	in Indust.	in Services
India	659	3,300	190	52	36	242	71	11	18
Indonesia	143	1,920	370	53	62	237	59	12	29
LDC	2,260	33,780	230	57	51	463	71	14	15
Malaysia	13	330	1,370	68	60	767	51	16	33
Tunisia	6	164	1,120	58	62	618	35	32	33
MDC	985	38,700	1,420	61	72	1,225	43	23	34
France	53	547	9,950	74	99	4,995	9	39	52
W.Germany	61	249	11,730	73	99	6,680	4	47	49
HDC	671	30,430	9,440	74	99	7,892	6	38	56

(1 billion $= 10^9$): GNP ~ \$100 billion, annual central government, budget ~ \$10 billion and of order 10 public sector/ private sector corporations worth \$1 billion each. (This is one reality, the other reality — \$100 per capita GNP). Let us assume 1% of any literate population has scientific research potential. A country of 6×10^8 with a 2% growth rate and 30% literacy would have a pool of $6 \times 10^8 \times 0.02 \times 0.3 \times 10^{-2} \simeq 3.6 \times 10^4$ people per year capable of research. Even if one in ten out of those can surmount personal or economic difficulties, the nation still has a pool of $\sim 4 \times 10^3$ first class minds to draw on, each year. Thus it is possible for a country where bullock carts are routinely used, to still competitively export engineering goods and run to its own nuclear power plants. And it is thus not impossible for villages without power and light to coexist with the technological capability to launch a satellite. It is the scale that permits extremes to exist within the same national boundaries.

Now let us rescale our macroscopic parameters, and state our problem -

Grouping	GNP per cap	Literacy	Life expect	Agric	En. Cons per cap.
HDC	1	1	1	1	1
LDC	.03	.4	.7	12	.06

"Development" = improve these ratios

"Science" = Basic Research on Pure Physics, Chemistry, Biology, Mathematics.

Q: IS THERE ANY CONNECTION BETWEEN SCIENCE (IN A COUNTRY) AND DEVELOPMENT (IN THAT COUNTRY) ?

By "development" we will mean an improvement in the life of an ordinary individual such that there is an improvement in the first three ratios. (This may not necessarily be connected with the other ratios becoming the

same. There may be different roads to development.) We will use the word "science" in a restricted sense, meaning only pure scientific research in physics, chemistry, biology and mathematics. This will refer thus to research motivated by the intrinsic interest of the phenomenon, to be distinguished from applied research or product development, where one tries to optimize the useful parameters in an already known phenomenon. Our basic question is then: "Is there a necessary and direct connection between science in a country and economic development in that country?" (Subsidiary question: Why should an LDC government support scientific research?) The direct connection mentioned above has to do with convincing a sceptical bureaucrat. He will base his future allocation on his judgement of scientific performance, based on the reasons given for such support.

II. SCIENCE → DEVELOPMENT (PAST)

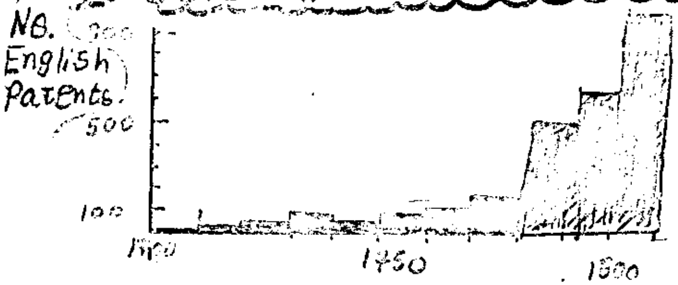
Having estimated the relevant parameters and stated the problem, one should first do a "literature search", i.e. see what has been done in the past.

The HDC's were once LDC's. Or, rather, there was a time when the concept of "D" did not exist. A phase transition occurred in England in the 18th-19th centuries, that changed man's intellectual outlook and his methods of production, and then influenced the rest of the globe: "The Industrial Revolution".

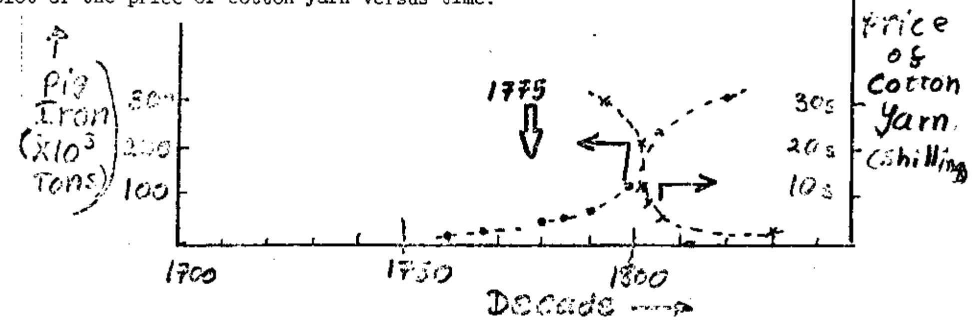
W. Rostow in "How It All Began" points out that ancient empires could only conceive of a steady state ideal, and quotes Confucius regarding the goals of government "People must have enough to eat, there must be a sufficient army and confidence of the people in their ruler". No mention of stimulating economic growth, aiding technological development, or social reform, all taken for granted today. The idea of a steady improvement in material well-being was new - the idea of Progress. The Revolution consisted in great new changes and increases in production and consumption, associated with an increase in innovation and invention.

Consider a histogram of English patents per decade versus decade. There is a steady increase, from 92 in 1760 to 924 in 1810, a factor of 10 in 50 years (with a doubling between 1790 and 1810).

1. Science → Development? (Past)



Consider a plot of the production of pig iron versus time, and another plot of the price of cotton yarn versus time.



Around 1796 there was a rise in steel production by a factor of 4 in 20 years, and a drop in yarn prices from 30 shillings a unit in 1790 to 3 shillings a unit in 1830, a factor of 10. There are many different reasons for these and other changes — this is a many-order-parameter phase transition. But with hindsight, one can state that the explosion in invention and innovation included one particularly important development around 1775, marked by the arrow. If we ask

Q: What was the cause? the answer in a schematic sort of way would be A: Watt was the cause.

James Watt. Son of a carpenter and merchant, he went to grammar school where he showed mathematical talent. He became a mathematical instrument maker at the University in Glasgow where he met J. Black, the physicist and was introduced to scientific developments including Black's ideas on latent heat. Between 1765 and 1775 he developed the idea of a separate condenser and a steam-jacketed cylinder to improve the (already existing) steam engine. In his own words, (quoted by Rostow) "To avoid useless condensation the vessel in which steam acted on the piston ought to be always as hot as the steam itself". By 1800, 500 of Watts engines were used to pump water out of mines, operate blast furnaces and in spinning and textile mills, etc.

Watt was not a professional scientist, but what we would nowadays call a technician. But he did have contact with the scientific community of his day. He was a member of the Lunar Society that included Black, Priestley and Erasmus Darwin, and helped Priestley in experiments on the constituents of water. When asked about the influence of Black on his work, Watt answered in the quaint phraseology of his time, "Although Dr. Black's theory of latent heat did not suggest my improvements on the steam engine, yet the ..... correct mode of reasoning and of making experiments of which he set me the example certainly conduced very much to facilitate the progress of my invention".

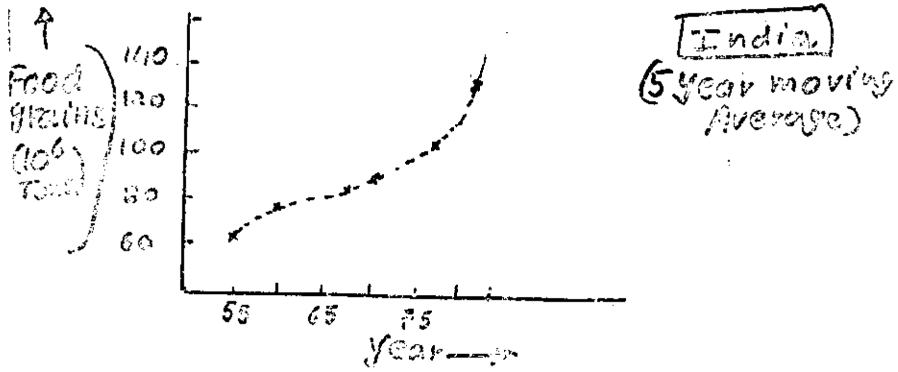
So at least in the 18th-19th centuries when It All Began, there was no direct connection between science and development. But science did "facilitate the correct mode of reasoning" of the artisans who came up with improvements.

Scientists ~~~> Artisans ———> Development
↑ etc.

Science changes man's world view, new technology is then developed by non-scientists within this changed world view, and if other factors (etc.) are present, this leads to development. The people doing research are not the same as the people involved in improvement of production methods. One cannot say with certainty that a new scientific idea immediately led to a specific new method of production. The connection between science and development was not direct.

III. SCIENCE ⟶ DEVELOPMENT (PRESENT)

Can one find examples where, at least, there has been an immediate economic payoff from scientific research? Consider the following graph of food production in India versus time. Clearly, there has been an increase by a factor of 2 in 20 years, with much of the change occurring from the early 60's.



The largest increases have been in wheat production. In the early 60's new High Yielding Varieties (HYV) of wheat, developed at the International Centre for the Development of Maize and Wheat, Mexico, were introduced in the Punjab.

Year	Wheat (10^6 Ton)
64-65	12
68-69	18
69-70	20

Year	Wheat (Hectares)	Punjab HYV
66-67	.7 million	
67-68	3 Mill.	
69-70	10 Mill.	

↑ Fertilizers x4
Yields x2
Tractors: 5000 → 13,000
Tubewells: 7000 → 100,000

~1962 Int. Centre for Improv. of Maize and Wheat — Mexico (FAO)
+ Punjab Agric. Univ. etc.

The new HYV what was first grown on demonstration farms, then taken up by private farmers in a big way. Punjab Agricultural University played a significant role, training extension workers and holding summer schools for farmers in the use of new fertilizer and methods. Large increases occurred in the number of tractors and tubewells in just three years. The average income of Punjab is now closer to an MDC than an LDC.

Clearly, on some scale development has taken place (although not without other associated problems) and science has been involved - genetics, chemistry, physics, with Ph.D scientists contributing in producing the seeds. As 70% of the population is in agriculture, if one could extend this to other crops, etc., one would be able to say science → development on an even larger scale. It looks like we have found a modern counter-example to the previous thesis that science affects development only indirectly, through non-scientists. Thus we can write schematically

Scientists - - - → Applied scientists, technically educated public ⟶ Development
↑ etc.

But go back to our original question: Is science <u>in a country</u> necessary for development in <u>that country</u>? A case for science based on such an example, falls to the ground. The research for the HYV wheat was primarily done outside India, although modifications were introduced in the country later. Even if science is necessary, it need not be done in the same country. In fact, on reflection, the MDC's like Singapore and HDC's like Japan provide counter examples, i.e. prosperity, independent of locally based feedback between the laboratory and the factor floor. Ironically, it is only in fields like electronics in some HDC's that new physics break-throughs can be translated into new economic industries in that country. But although there may not be a direct and obvious connection between a nation's science and its development, a case can be made.

IV. A CASE FOR SCIENCE

At least three reasons can be given for why science should be done in an LDC and why a tiny fraction of the GNP should be set aside for it (the vast majority of expenditure, of course, being devoted to immediate needs).

1. The argument from aesthetics/national identity

Science is creative, the structure is beautiful, and like any artistic traditions it can be easily destroyed but less easily created. It need not cost very much in proportion to a countries GNP, and the nation will need it later. It should be supported for the same reason that national art forms are encouraged, as one expression of the creative abilities of the people. Moreover, the reasons why a particular country rises or falls historically, are obscure. A national self-confidence and identity may play some role in economic development, creating a climate where a person with a new idea (in any field) is not afraid to try it out. Science of international quality that is done, and seen to be done, could play a role in providing this climate.

2. The argument by continuity (with applied science/teaching policy/technology transfer)

Applied science, the teaching of science to engineers and technicians and the existence of a national pool of scientifically literate advisors and consultants, all require pure science to be done within the country. Like any living intellectual tradition, science is indivisible and often those who have done pure research can pass on even text book knowledge in a way that may help a future technician to understand the principles of the subject, rather than memorize results. In any complex society, a division of labour is necessary, and the network of specialized services on which the society depends will include those far removed from immediate application. To demand that every single human activity have an immediately demonstrable 'relevance' is to miss this organic complexity. It is like demanding that a tree produce fruits without roots.

3. The argument by social reform

Many LDC's are new nations with old cultures. Age is equated with wisdom, old evils are sanctified, societies are fragmented by linguistic, caste, and class divisions. Pure science is one of the few national enterprises that is

i) sceptical and questioning in its outlook, where youth is no bar;
ii) potentially a nation-wide unifying subculture, blind to national divisions;
iii) rational and anti-superstitious in its world-view, displacing old beliefs, revolutionary in its implications.

Science should therefore be supported as a catalyst for desirable social change, which is surely included in the broadest view of development.

In conclusion science is necessary, but not sufficient for development, But it is necessary in subtle, non-obvious ways. Science is not a protein that can directly produce economic muscle; rather, it is an essential vitamin necessary for health and growth.

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NEPAL

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Distinguished Participants,

I would like to begin be expressing my sincere appreciation to the International Centre for Theoretical Physics for giving me this opportunity to express my views on the important problem of 'Physics and Development'. Since Nepal is one of the least developed countries in the world, there is little to talk about physics and its impacts on development in Nepal. While addressing this distinguished audience, I would, hence, like to take the opportunity to express my views about Nepal in a nutshell and the constraints imposed to the physicists.

Wedged between the Tibetan Autonomous Region of the People's Republic of China in the north and the Republic of Indian Union in the east, south and west, Nepal is a land-locked country, the nearest sea-coast being about 1120 kms away in India. Its total land area is 145,305 square kilometres. She is, therefore, about 22 times smaller than India and about 70 times smaller than China. Roughly she is about the size of Bangladesh. The population of Nepal according to the census of 1981 is 15,020,451. The population of China and India is about 60 and 44 times more than that of Nepal respectively. Hence we often use the imagery 'a yam between two boulders' in Nepal's geo-political content.

The low lying fertile and plane Terai Region in the south occupies only about 17% of the total land area. The rest of 83% land area is occupied by high mountains, a few charming lakes and many snow-capped mountain peaks including the Mt. Everest (8,848 m), the world's highest peak. There are more than 240 peaks over 20,000 ft (6,094m)above M.S.L. and 7 out of 10 highest peaks in the world are located here in the Great Himalayan region which lies in the north. The climate ranges from widely-subtropical in the Terai, to moderate

in the central valleys and to alpine in the Himalayas.

Nepal is one of the most ancient kingdom in this part of the globe as it has been alluded to in the Hindu myths and legends dating back to pre-historic times. The present territory of the kingdom of Nepal was established by king Prithiwi Narayan Shah, in 1767 A.D. A stormy chapter began in her history in 1846 A.D. with the usurpation of power by Ranas. The Rana family oligarchy lasted for more than a century. In February 18, 1951, oligarchy gaveway to democracy and Nepal opened its doors to the outside world. Since Nepal is sandwiched between India and China, the people of Nepal show a blending of the Asian stock in the Terai and Mongoloid blood in the cold Himalayan belt. In between these two, the population varies from pure Asian to pure Mongolian and a varied mixture of the two. Nepal's culture is, hence, blending of the individual and social impulses of these two major races of mankind. The Nepali culture has been able to preserve its unique character because not once in the history of Nepal has it been subjected to foreign domination.

Though the constitution of Nepal has declared the country a Hindu state, Buddhism is yet another major religion. The extreme degree of mutual tolerence shown by the followers of these two faiths towards each other in Nepal, as described by the seventh century traveller-historian of China, Hue-in-tsang, at that time has remained unchanged till now. The timeless coexistence has amply manifested itself in Nepalese art, architecture and sculpture and is so pervading as to influence the entire fabric of what may be called the Nepalese culture.

When Nepal awoke to the realities of the contemporary world in 1951, it had no economic and social infrastructure to speak of. A century of very slow development process in Rana Regime dropped the position of Nepal to one of the least developed countries of the world. Very little education facilities with the least chance to develop nationalism, poorest roads and transport routes, scanty communication channels with the outside world and complete secrecy of the national budget made the country undeveloped. There was a strict control on the entry and movement of any foreigner. Inquisitive foreigners never got a chance to know Nepal and Nepalese people. While other nations advanced in science and technology and schemed themselves for the take-off stage towards interplanetary travels, Nepal kept herself completely aloof- concerned. Others took the necessary forward steps and Nepal was left behind - many - many years behind.

Now, let me seek permission to speak in brief about the development work in the period of the last three decades.

Agriculture, the mainstay of our economy, contributes over 60% to the country's G.D.P. and engages over 90% of Nepal's economically active population, despite the fact that a mere 14% of the country's total land area has been brought under the plough. Agricultural products also contribute roughly 80% of the country's export. The total land under irrigation facilities in 1951 was 250 sq.Km. and now it is about 3,700 sq.Km. The forest area forms some 32% of the total land area. Sal, fir and chirpine are some of the principle Nepalese timbers. More than 30 species of large wild mammals like elephant, rhinoceros, tiger, leopard, bear, deer etc. roam the forests. Though a formidable task due to her mountaineous terrain, Nepal has accorded a high priority to road buiding. Prior to 1956, the country had a total of 259 km all-weatner road. Now the total length is about 4,800 km. The 102 km railways were constructed in early 1930. The development of road transport made them mostly reduntant. In 1951, there was only one airport and now the number of airports is 42. Up to 1960, no telephone was in use but at present the number of telephones in use is more than 11,000. There are 78 wireless stations for public use in various parts of the country. Microwave links also connect various parts of the country with each other. External communication links connect the country with all countries of the world through telegraphic, telex or trunk telephone systems. Postage stamps were issued in Nepal for the first time in 1881. In 1955 there were 182 post offices which have now swollen up to about 1,400. The potentiality of Nepal to generate hydroelectricity has been estimated as 83,380MW. But in 1951, the production was only 6.3MW which stepped up at present to the total of 149MW. Over the centuries, this 'sangri-la' land remained virtually isolated from the rest of the world. Nepal has so far established diplomatic links with about 80 countries while this number was only 4 in 1951. Up to 1956, no data of tourists is available. The number of tourists in 1961 was 6,179 while in 1979 it increased to 162,760. By the end of 1978, there were 68 hospitals with only 2,309 beds, 35 health centres, 433 health posts and 82 Ayurbedic dispensaries. The doctor/population ratio is still around 1:30,000. Though Nepal launched her industrialization programme in the mid-thirties, the planned industrial development got underway only in 1956. At present 7 industrial estates are running in different parts of the country. Jute, cigarettes, leather and shoe, brick and tiles, cement, distillery and brewery and cotton textile constitute the main products.

Starting with 1% literacy the post-1951 era has, indeed, witnessed a remarkable growth in literacy in Nepal. About 20% of the country's population is now literate, while the country's primary, middle and high schools roughly totalled 334 around 1951, this figure has swollen to 13,601 in 1979, with

1,463,996 students and 41,185 teachers.

The new education plan, designed in 1971, is 'primarily aimed at counteracting the elitist biased view of the inherited system of education by linking it more effectively to productive enterprises and egalitarian principles'.

The plan also 'seeks to replace the concept of education as a means to white-collar-jobs by a new concept that regards education as an investment in human resources for the development of country'. Under this plan, Nepal's educational structure has been divided into two levels-school level and higher education level. The country's only university, Tribhuvan University, established in 1959, impacts higher education through a number of campuses under it. The number of campuses is about 125 with about 3,000 teachers and 35,000 students. Of this a very small fraction, less than 10% is enrolled in science education.

Now let me present the national picture in Physics in Nepal. There is an acute shortage of mature physicists, skilled technicians and advanced students for effectively pursuing research in physics and its related areas in Nepal. Up to 1966, one had to go outside the country to study physics, resulting only 17 persons holding Master level degree in physics at that time. Today the number stands around 85 with only 7 persons holding Ph.D. degree. About 4 or 5 are added annually in this stream, most of them graduating from T.U.. Tribhuvan University has not, yet, started Ph.D. programme in physics.

About 75% of this population are engaged in teaching at campuses while 10% are employed in technical departments under His Majesty's Government of Nepal. The number of physics graduates employed by the industrial sector is virtually nil, which can be viewed as an indicator of the low level of development of our country.

Since progress in physics requires a solid scientific foundation including sophisticated methods of experimentation and computing, the constraints imposed by the lack of adequate laboratory facility has inhibited the growth of our research and development work in physics. For instance our physics graduates do not have the opportunity to learn many basic experimental techniques such as workshop practice, computing and so on.

It is beyond doubt that there is a very small rate of annual production of physics graduation at T.U. which is mainly due to the constraints imposed by the lack of equipment and laboratory at campuses. A lack of qualified students leading to the fall in the student enrollment is also a limiting factor in the rate of expansion in the field of physics. In this connection, I would like

2. Physics of the earth

a) Crystal structure.

b) Gravity - magnetic - Radiometric anomalies.

c) Rock magnetism, Paleomagnetism.

d) Heat flow measurement.

3. Physics of the atmosphere

a) Structure, dynamics and interaction of the different atmospheric layers.

b) Radio - Meteorology.

c) Atmospheric electricity.

d) Physics of the ionospheric layers.

e) Geomagnetic mainfield and secular variations.

4. Radiophysics and electronics

a) Physical electronics and devices.

b) Electromagnetic theory and practice.

c) Propagation conditions for LF,HF, VHF and UHF communications.

5. Physics of the material and solid state

a) Electrical materials - conductors, insulators, semiconductor.

b) Magnetic materials.

c) Amorphous solids.

d) Construction materials.

e) Fibers, polymers, wood, soil, ceramic and glass.

6. Radioisotopes and Radiation Physics

a) Radioisotope datings.

b) Applications of radioisotopes as tracers.

c) Cosmic rays.

Recently we are also thinking about the possibilities of establishing a laboratory at high altitude in the great Himalayan region where the experiments and studies on cosmic-rays, the upper atmosphere, the Himalayan glaciers and geophysics can be done.

Naturally, a degree of excellence in these areas demands a balanced growth in the different branches of fundamental physics, which in turn, will help to advance physics and its related areas as a whole.

The priority of the above research project is determined by the required economic input, the necessary technical infrastructure and the available manpower in the field, all in their proper weight. An adequate computing facility, a well equipped library and a laboratory with the facilities for production and measurement

to concern over the job incentives which influence the student choice. Until now the major role assigned to our physics graduates has always been either to train the necessary manpower for teaching basic physics or to teach basic physics to undergraduates who will pursue their careers as engineers, medical practitioners or technologists. Unfortunately the fate of the majority of physics graduates teaching at campuses has been to spend all their semester time on coaching and examining large classes of elementary students, leaving only the vacation free for reading and writing in an ill-equipped library.

After the introduction of the new educational plan, the institute of higher learning has included some of the basic ingredients of research as part of the degree level studies in the fields of atmospheric physics, geophysics, ionospheric physics, nuclear physics and solid state physics. These degree level research activities bear close relevance to the needs of the technical sector of H.M.G. of Nepal. Hence in 1976, the National Council for Science and Technology (N.C.S.T.) was established with the objective to frame a national science and technology policy.

So far as R & D in physics are concerned, they give a reasonably good measure of the standard and health of science and technology in the country. In fact, the maturity of the scientific knowledge seems to have come, in general, in those areas where knowledge of the subject matter is employed in conjunction with physics. Hence some measures are, now, being taken by RECAST (Research Centre for Applied Science and Technology), established in 1976, to enrich and develop the indigenous capacity and capability on the area of science which are most relevant in the national context for the proper assimilation and development of science and technology.

Since the earlier and the current national development plans put considerable stress on the development of natural resources, the feasibility study as well as the scheme for the utilization of the natural resources have been a major theme of the current five year plan. In this context some areas for R & D in physics and its related areas, as suggested in 'A report on research in Physics in Nepal'[1] is as follows. This incomplete list, which is neither exhaustive nor in the order of priority, gives an idea where R & D in physics in Nepal are being considered through a proper programming and planning.

1. Energy resources and devices :

a) Energy conversion, conservation and storage.

b) Solar energy and solar devices.

c) Other energy resources and devices.

of low and hgih temperature, high pressure and high vacuum and spectroscopic measurements are very important requirements for modern research. But research efforts may not be postponed until the full developement of the ancillary facilities. Hence areas are being identified where meaningful and relevant work could be conducted with the necessary resources that may become available.

It is recognized in our country that for the implementation of science and technology in a meaningful manner, cooperation from other developing countries, international organizations should play a more active role in establishing an appropriate mechanism for the provision of adequate information in science and technology to help them substantially to develop their own capabilities in assessment, selection, absorption, general and application of science and technology. For these purposes harmonization in the objectives and policies of different international agencies and coordination in their programme in the developing countries is necessary.

The death of good science in the developing countries may be traced to the general poverty of our people, discriminatory facilities between scientists and administrators, feudalistic exploitation of the working scientists, lack of encouragement and bureaucratic set-ups. Science and technology do not attract some of the best. Those who would potentially be the great scientist of the future are either drifting to professions other than science, due to the lure for power and perquisites or gravitating to the U.S.A. and western Europe where better opportunities exist. Hence, development of a centre of excellence is also a basic need for developing countries, nationally where possible and collectively if necessary. C.V. Raman has remarked once that "There is only one solution for India's economic problems and that is science and more science and and still more science" which seems to be equally applicable to the other developing countries, too.

Lastly, but not least, let me express my admiration for the initiative taken by the International Centre for Theoretical Physics to make physicists conscious of the problem of physics and development. My thanks are due to Professor Dalafi and Professor Ghirardi for inviting me to deliver this talk. However, the views expressed within this talk are my own and those need not be of the institute to which I belong.

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S O U T H   A S I A

HISTORICAL PERSPECTIVES FROM SOUTH ASIA

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INTRODUCTION

It is a truism to say that the vast majority of world population does not have access to food, shelter, health, education, communication and entertainment of the standards which are normally considered acceptable. This fact is brought out in a set of pictorial charts by the authors of the book, "Catastrophes or New Society? A Latin American Model" [1]. What these charts reveal is a dismal story, further accentuated by the contents of Table 1. The tables reveal that over two and a half billion people in the world have per capita annual incomes ranging from around US$150 to US$350. Compared to this there are a billion people who enjoy per capita annual incomes in excess of US$4000. If compared to the ASHA development index [*] the gap between the low income group and high income group becomes 1 : 250. [2]

Has this always been the case? The answer is no. The vast gap between the living standard of people in different parts of the world is a comparatively recent phenomenon. It is true that the vast majority of world's population has always lived near subsistence level. But on the average the common people everywhere, be they in Asia, Africa, or in Europe enjoyed more or less similar living standards. The gap started to widen since the last decade of the eighteenth century and has continued to widen even more. In a recent study Paul Bairoch has tried to quantify the per capita annual incomes in the so-called developed and developing countries since the Industrial revolution. His study has shown (Table 1) that in the year 1750, per capita annual incomes in the developing countries were slightly higher (about 188) compared to those prevailing in countries now labelled developed.

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*) ASHA development index is defined by the ratio obtained by dividing the product of (growth rate x employment x literacy x life expectancy) by the product of birth rate and infant mortality.

From then on the incomes in developing countries started to decline until about the year 1900. Rising only very slowly after that to become US $355 in 1977. Compared to this the incomes rose steadily in the developed countries rising to $540 on 1900 and to the present high in 1977 (see Table 2). What has been the cause of this disparity in incomes in different parts of the world? The most often cited cause is the initiation first in England and then its spread through-out the developed world, of the Industrial revolution. Western European countries thus developed their economic and technical power to dominate and colonize most of the developing countries, leading to their decline. Science and technology are said to have played the major part in this success story of the West European countries. While it is true that science in its pure form hardly played any decisive role in the initiation of the Industrial revolution, but subsequently and especially since the later half of 19th century, new science based industreis, chemicals, electrical, nuclear, electronics, telecommunication etc. have come to play a major role in the economic well-being of developed countries. It is therefore argued that developing countries, who have been left backward under long colonial rule, must now rely on science and technology to overcome their backwardness and underdevelopment. Science and development have thus come to be associated together, In the next section we would examine the connection between science and development in the developing countries.

SCIENCE AND DEVELOPMENT

If one studies the developed countries be they old centres of economic and political power like Britain, France, Holland, Germany or new ones like U.S.A., U.S.S.R., countries of Eastern Europe, Australia, Canada and Japan, one observes that these countries also have the largest number of scientists per thousand of population. According to UNESCO, OECD studies, "86% of the total number of scientists and engineers working in the world are centred in a zone which embraces North America, Western Europe, Eastern Europe, U.S.S.R. and Japan. This zone is inhabited by only 30% of world's population. If one reckons only that part of this category which is devoted to research and development (R & D), the concentration appears even more powerful". It reaches 94%. Needless to say that all the countries in this zone are in the category of developed countries.

If one survey the professions in these countries one further observes that in the U.S.A. and U.S.S.R. about 20% of the total population has degrees in science and engineering. In Europe and Japan the figure is still 10%. In most developing countries this number varies from 0.04% (Kampuchea) to 2.7% (Phillipines). For India it is 1.5%, while for Pakistan it is 0.2%. The connection between science and development signifying economic well-being seems to be well-established. The developing countries are therefore urged to develop their science and technology if they ever hope to overcome their present state of backwardness and underdevelopment. One feels like agreeing with this observation. But is it true that mere development of science and technology will automatically lead to development? There is one very good example of a big country which is scientifically very advanced but at the same time economically very backward. The country is India. Let us examine her case in greater detail.

SCIENCE IN INDIA

India has the third largest stock of scientists and engieners, after U.S.A. and U.S.S.R. in the whole world. In 1977, she had 2.3282 million qualified personnel with degrees in science and technology. In the years (1974-75) her one hundred and twenty institutions of university status had on their rolls over 2.366541 million students. Her educational system trained over 100,000 undergraduates in science, over 30,000 graduates in science, over 15,000 engineers and technologists, over ten thousand doctors, over 5000 graduates in agriculture and over 1500 doctorates in various disciplines of science and technology. She employs over 50,000 personnel primarily in R & D activities and over twice this number in auxiliary and supporting activities. She spent over 400 million US$ on R & D activities in 1976-77 (see Tables 3-6 for details).

She has well developed institutions for science. There are 149 such institutions, 4 under the Central Government, 168 under various ministries of Central Government, 166 institutions are under state sector in various provinces. Private sector manages 348 R & D institutions (see Table 8 for details). From the very early days of independence the Indian Government adopted a well thought out policy for science and technology. The Indian Parliament adopted a science policy resolution on 4th March 1958, through which it resolved besides many other measures; "to foster, promote and sustain by all appropriate means, the cultivation of science and scientific research in all its aspects - pure, applied and educational", and in general, "to secure for the people of the country all the benefit that can accrue from the acquisition and application of scientific knowledge". [4)]

Indian scientists are very intimately involved in planning and execution of the science policy. They are on the highest National Council on Science and Technology, which works directly under the Prime Minister of India.

The achievements of Indian science and technology are many. Her scientists publish every eighth research papers which is written on science and technology anywhere in the world. She has exploded an atomic device, sent her own satellite

into the sky, constructs her own atomic reactors, ships, aeroplanes, tanks, etc.. Her scientists can be found in almost every university and scientific laboratories of the western world. India is undoubtedly a scientifically and technologically developed country. Her heavy machine tool factory is in the rank of top ten machine tool manufacturers of the world. Bharat Heavy Electrical Ltd is the sixth largest company in the heavy electrical machinary sector in the whole world. Indian industries can manufacture paper plants, cement plants, sugar mills, textile mills and medium size steel plants. [7)]

But this is only one side of the story, the brighter side. "The present poverty population [*)] of India"is estimated to be 309 million" (nearly half the population). "The total number of rural poor continues to grow by about 5 million per year." (Raj Krishna: The Economic Development of India, Scientific American, Sept. 1980). At the same time income inequality is glaring."The top ten percent continue to account for 51% of the rural assets". Infant mortality is 134 for 1000 live births. Life expectancy is 52 years and G.N.P. per capita in US$ is only 180. (See Table 8 for details and comparison with U.S.) There were 9,609,000 people unemployed in 1976. Among them over 909,000 had graduate and post-graduate degrees and over 2.5 million had high school and undergraduate certificates and degrees. Every year five million young are added to the work force. The modern industrial sector is able to employ only 12% of these. Indian population gets only 88% of the established standard of calorie supply per capita. [8)]

All the above facts reveal a dismal picture of the Indian scene. Science and technology have developed greatly in absolute size (No of scientists, publications, institutions, expenditures on R & D, achievement of individual scientists, etc.), but judged in the context of overall Indian society, the impact of science and technology could be called marginal, or minimal. What is quite obvious is the fact that a number of countries like Japan, Holland, Belgium, Sweden, Norway, Denmark, Canada, Australia etc. who have far less number of scientists and much smaller scientific establishments enjoy musch higher standards of living with some of the highest development indicators. Why is this so? Why has science in India not been able to do as much for the Indian people as science in many European and non-European countries has been able to? The reasons are many, and they are to be found in the peculiarities of Indian science. These peculiarities have to do with the way present Indian science has evolved from its beginnings in the colonial period to the present era.

*) Poor households are counted as those having monthly consumption of less than US$8 in rural area and $9 in urban areas.

Modern science in India was introduced on a significant scale through British colonial authorities. From the very beginning it was an extension and appendage of British and European science. Even its early practitioners were non-Indian. By the middle of the 19th century, however, educational institutions were opened on a limited scale to import scientific knowledge. But the basic idea of the scientific eduational system was to train low level manpower to run the scientific based institutions which colonail authorities had created to facilitate, safeguard and promote the hold of colonial powers. As one colonial official W.S. Blunt, so clearly stated in his diaries; that the huge colonial empire of Britain was kept under her hegemony, "in parts by concession, in parts by force and in parts by constant intervention of new scientific forces to deal with the growing difficulties of imperial rule". Science was therefore not an instrument of liberation as in Europe but an instrument of colonial rule. When in later decades of the 19th century an upsurge of Indian nationalism took place a number of prominent Indians like R.C. Sahni, R. Sikdar, P.N. Bose and P.N. Datta, M. Sircar, J.C.Bose, D.C. Roy and J.C. Tata promoted the study of science among Indians. It is mostly through their influence that Indian science got a large number of Indians interested in scientific studies. Many Indian scientists made their name in pre-Independence era, like C.V. Raman, K.S. Krishnan, M.N. Saha, S.N. Bose, H.J. Bhaba, Vikram Sarabhai among others. But instead of being an integral part of the evolution of Indian society science remained basically an elitist activity, largely impervious to and immune from Indian reality. It became integrated to the European science and got itself alienated from Indian people, their aspirations, their frustrations, their problems and their hopes. It remained "marginal and essentially of a basic nature." Even after independence it developed largely on the foundations and organizational patterns evolved during the colonial era. Its expansion has been basically quantitative rather than qualitative. "Research Publications" by Indian scientists "continue to be imitative and an extension of ideas developed elsewhere". This is borne out by to the fact that judged by the number of scientists engineers per thousand of population (1.1), by the No of scientists engineers engaged in R & D per million of population (46), by the expenditure on R & D per capita (US$ 0.66); India is among the lowest of the developing countries. All the above data are from UNESCO Statistical Year book of 1981, and pertains to the year 1979 for India.

The question naturally comes to mind; why was Indian society, in which knowledge (of science, technology etc.) was integrated with the society during the pre-colonial era, transformed into a society, in which scientific knowledge came to be of marginal nature. The other question which naturally arises, why India did not from a stage of comparable economic development during the 18th century, initiate a scientific-industrial revolution of her own? To look for clues, for answers, a digression into the history of late medieval Europe and

India is required to define the stage at which the paths of these two societies started to diverge.

HISTORICAL DIGRESSION

Historically the biggest innovations in production techniques in modern history were introduced in England during the last three, four decades of the eighteenth century. Since then the pace of introduction of new technical innovation has quickened greatly. The total production of coutries in which these innovations have been introduced has increased at a very great pace. This revolution in production technique has been given the name of Industrial revolution. Its birth in England in the 1760's and its subsequent spread to Holland, France, Germany, U.S.A. has been well documented. The class which prepared the ground for this revolution and which subsequently came to rule in the above countries has been described by the name of bourgeoise or capitalist. What is of interest to us is the fact that in all countries where this class did not have a significant role in the whole matrix of ruling groups, the Industrial revolution either did not take place or was inordinately delayed. The most significant examples in Europe are Portugal and Spain, who in the 17th century were powerful empires. In Asia, China and India were economically very powerful countries. Besides the Ottoman Empire was another powerful state in the eighteenth century having under its control the whole of Balkan, Greece, North Africa and the Arabian Peninsula. What happened later is well known history. West-European countries led by England, Holland and France taking advantage of their newly gained technical superiority and new world outlook, established their empires all over Africa, Asia and Oceania, overcoming the resistance of native kings, nobles and tribal chiefs.

Our main concern in this essay is to inquire into the reasons for the failure of the industrial and associated technical revolution to take place in South Asia. This is a subject which has been discussed at great length by foremost scholars. Even now it excites great academic debates. In the following we will summarize the main arguments of the debate and then propose our own point of view.

STATIC AND STAGNANT SOCIETY

Among the first arguments to be put forwarded for the failure of Indian society to initiate an industrial and capitalist revolution of its own was the fact that Indian society was very traditional, cast ridden, static and stagnant, impervious to any change in its social structure mainly due to the other wordly fatalist attitude of its population. Similar argument was put on a more rigorous economic footings by Marx, who argued that Indian society was of a very special type, characterized by a self sufficient and hence unchanging village economy. According to Marx this society was dominated by a new mode of production not observed in Europe. He named this, the Asiatic mode of production. This mode, according to Marx was characterized by the absence of private ownership in land, a strong centralized state, which organized and supervized large scale irrigation networks, levied the land tax and owned the entire land. Marx argued that in a period of weakness of such a state, the agrarian sytem suffered and the system became liable to destruction or takeover from outside. At the time of British colonial onslaught India was passing through such a phase and hence collapsed under the colonial impact. Marx, however, considered the colonial impact to be progressive, in the sense that a new vigourous society might emerge after the shattering of the old static one.

This view of static society, put forwarded by the apologists of colonial rule , was accepted for a long time, even by such a fierce critic of colonization, as Marx. But studies of Indian history in medieval times, especially in the sixteenth to the eighteenth century pre-British era have revealed new facts, to demolish this view and question the concept of the Asian Mode of Production. Historians like Irfan Habib,[8] Mukerjee, T. Raychaudri have presented ample evidence to show that far from being an unchanging static society, India was during this period, a dyanmic society, having a large (upto one fifth) urban population, vigourous commercial activity, a booming export trade and a state of techniques of manufacturing as good as anywhere in the world.

NASCENT CAPITALISTIC ECONOMY IN ITS INITIAL STAGES OF TAKE OFF

The other most important point of view has been that at the arrival of British colonial power in the later half of the eighteenth century, India though no longer centrally governed as in the seventeenth century, was the centre of vast manufacturing and long distance sea trade. Her trading class having a number of very wealthy merchants had extensive experience of commerical activity and long distance trade even prior to European arrival on the scene in the last decade of the sixteenth century. The proponents of this view argue that this merchant class was countinously increasing its influence and power and could in due time develop into a well-developed capitalist class capable of launching its own capitalist and industrial revolution. But the advent of the British in the second half of the eighteenth century killed in its nascent stage this budding capitalist class. Its thriving manufactures were destroyed, its cities depopulated, its wealth transferred out of the country, her merchant class subordinated, thus forestalling the possibility of any independent internal development of Indian society. The debate about the possibilities of capitalist development in pre-British India has been very scholarly and exhaustive but inconclusive. But the important result of this debate has been, to demolish very effectively the myth of pre-British static Indian society, and to produce vast amount of historical facts to demonstrate the existence of large urban population, commercial activities on a vast scale and inter-continental trade by Indian merchants, thriving manufacturing activity in textile and other consumer manufacters. In the next section we will argue that the socio-political structure of pre-British India had features which problably required a very long historical period for the rise of an indigenous capitalistic class. We will argue on the following points: the significance of the merchant class among the ruling groups, the organization of work-process in manufacture, presence/ absence of a market economy.

PRE-BRITISH INDIAN SOCIETY

Ownership in land which is the hall-mark of feudalism in Europe was not practiced extensively in India. In general, the ownership of land rested with the emperor/king whatever the case may be. The whole land was leased out to few hundred nobles called Jagirdars, who were to collect revenue from the cultivators, keep a percentage to themselves, and handover the rest to the state treasury. In exchange they had to keep a certain number of mounted troops (e.g. five thousand, thousand, five hundred) and make them available to the king as required. The lease was in principle non-hereditary, and was usually transferred after a couple of years to another Jagirdar. As a result the title holder would hardly develop a close relationship with his tenants, as was the case in European feudalism. The cultivators would often hold hereditary tenancy rights. But they were left with little after paying various taxes. Vast incomes accrued to these title holder. Studies of contemporary records reveal incomes in excess of million ruppes to some. Each title holder maintained his own court and the money filtered down to the lowest levels. It thus led to the appearance of large urban centres near the place of residence of the king and his officers. Normally each of these officers would have manufacturies of their own, employing artisans and handicraftsmen to manufacture for their use. This led to the interesting case of large manufactures without the market playing any significant role. Markets did exist for grain and village produce, as the practice of collecting land revenue in cash was introduced in earlier centuries. The peasants however, only used the market to procure cash for his land tax. He would meet his necessities within the village through barter, exchanging his produce for the services of potter, weaver, carpenter, blacksmith, shoe-maker, priest, etc.

In the coastal areas, however, manufacture for export did develop extensively. But here too a primitive form of exchange between the merchant and weaver took place. The merchant would normally advance an amount of cash to the weaver, who would after sometime handover the finished product to the merchant. Now this is a very important point, as this relationship had important implications for the non-emergence of capitalism in pre-British India, we discuss this point in some details.

ORGANIZATION OF WORK PROCESS, AND INNOVATIONS IN PRODUCTION TECHNOLOGY

It has been observed historically that increases in production take place usually either through better organization of work process or through the introduction of new and better production technology. These innovations in the organization of work-process and process and production technology come about only when there is pressure to increase production. If existing work-process and production technique are able to increase production by mere increase in the number of workers, then no innovation either in work-process organization or production technology will take place. Further innovations in production technology usually require large investments, A class of entrepeneurs is needed to introduce innovations in work-processes.

We like to argue that the Indian merchants-weavers were able to meet the ever-increasing demands for export, by merely bringing in more weavers into the profession without any innovations in either the work-process or production technology. The Indian merchant did not succeed in a big way to evolve into a manufacturer, by the first controlling and advancing the raw materials to weavers themselves and later organising the work-process by bringing the weavers under some sort of factory discipline. The weavers remained in control of their work-process, organising it to suit their own time schedule. But they did not have enough of cash to invest in new production technology. Indian industry thus suffered from the absence of entrepeneurs to evolve into modern industrial manufactures.

As opposed to this Indian scenario, in England, the merchants rapidly evolved during the seventeenth century into industrialists, organizing the work-process, controlling the pace and timing of workers and introducing innovations in production technology. It is very interesting to note that during most of the eighteenth century increases in production in England took place by innovations in the work-process, i.e. the factory system, where workers were brought under one roof with existing technology and their pace and time of work supervised and controlled. This stage never arrived in India and could not have arisen as existing work-process and production techniques were able to meet ever-increasing

demands for manufacture throughout the eighteenth century.

The other class/group - the Jagirdars - which could be interested in technical innovation was at the most indifferent as existing methods were more than enough to keep him supplied with all his requirement and in splendour unheard of in Europe. Indian industry thus lacked the conditions in which it could evolve into higher form of machinofactures, as the ruling groups were content to live in luxury and the artisans were not rich enough to save for investment in innovation. Indian ruling class was not interested in saving for investment - all their incomes going into conspicous consumption. While European kings were investing in so the world sea voyages, Indian emperors were busy building magnificent palaces, gardens, forts etc.

Another important feature of pre-British Indian society was lack of all-Indian nationalism. It is true that during the eighteenth century, India was breaking up into regional kingdoms and some sort of nationalism was emerging like those of the Sikhs in Western India and of the Marwatas in Central India. But the majority of Indians still owed their allegiance to their tribal or clan chiefs. In the absence of a market, which has been an important factor in the emergence of nationalism, Indian nationalism did not exist. On the other hand, the breakup of old feudal holds in Europe had started the phase of nation formations. The English were the first, breaking away from Papal hegemony during Henry VIII's reign and organising an English Church. Further during the 1642-1658 civil war between the old feudal nobility represented by the king and the Parliament representing the emergent merchant class, the king was captured and beheaded, the whole of Britain, England, Wales, Scotland and Ireland unified by Parlaimentary forces. By the end of the civil war a unified Britain under English hegemony was created. Merchants and manufacturers emerged as the foremost powers in the whole Britain. Later developemnt further consolidated the British nation and the power of her native merchants and manufacturing class, increased immensely.

THE STAGES OF ECONOMIC GROWTH

The American economist W. Rostow has depicted pictorically the historical evolution of the economies of leading developed and some developing countries [11]. He distinguished the stages of take-off, of reaching economic maturity and reaching high mass consumption. Among the western nations, U.K. was the first to take off around 1760's, reaching maturity around the middle of the 19th century and entering high mass consumption in the early decades of 20th century. He has also indicated the evolution of U.S.A., France, Germany and so on. Rostow does not describe or inquire into why a country entered the take-off stage at a particular time. We have tried to give below very briefly some of the important events in social, political and cultural field, which in our opinion had a decisive impact on the time at which a country reached its stage of take-off.

First of all for all the developed countries of Europe the most important fact is the rise of the mercantile class to a position of importance in the sixteenth and seventeenth centuries and accompanying with it the great transformation in the philosophical and world outlook from that of Aristotelian-Thomastic cosmology of a closed, hierarchically ordered geocentric universe; with its emphasis on the ephemeral, transitory nature of life on the corrupt, biase and vile earth, governed by divine will and laws, which could only be learned through introspection, meditation and contemplative speculation; to that of an open, infinite, unbounded, heliocentric universe of Copernicus-Brahe-Bruno, governed by well defined laws, which could be discovered through painstaking, repeated observation and generalization based upon them. The emphasis also shifted to the earth and earthly life and to man. Fron the Scholasticism of the medieval times, the philosophical outlook changed to Inductivism (Bacon, 1561-1626), nomalism (Hobbes, 1588-1679) and empiricism (Locke, 1632-1704). Science became experimental-mathematical instead of being the contemplation'sf God's creation, through Galileo, 1564-1642), Descartes (1596-1650) and the Royal Society (1642-1688).

The changing mood may be examplified by Bacon who ridiculed the teleological knowledge by noting: "Teleology like a virgin, consacrated to God, produces no offspring". Acceptable scientific knowledge was now casual, not teleological. Truly Bacon could write: "Human knowledge and human power meet in one; for where the cause is not known the effect cannot be produced".[13)]

The war of religions in the sixteenth century leading to the founding of national churches in England and Germany, shattered the intellectual hegemony of Papal Rome. Frequent and prolonged peasants uprisings in central and western Europe lessened the hold of old established ruling classes. World wide travel which started in the last decades of the 16th century broadened the vision of a lot of Europeans. Great philosophical and scientific activity Copernicus (heliocentric world system, 1543), Kepler (laws of planetary motion, (1571-1630)), Tycho Brahe (unbounded universe, (1546-1601)), Galileo (1564-1642), experimental-mathematical method for science, use of telescope to discover moons of Jupiter, works on mechanins, Harvey (circulation of blood, (1578-1657)), chemical researches of Parcelsus (1490-1541) and Von-Helmont (1577), researches on anatomy, physiology and botany of Vasalius (1515-1654), and many others brought out a metamorphosis in the thinking of people all over Europe engendering a new spirit of adventure, inquiry, scepticism and nationalism.

The English civil war (1642-1658), restoration (1658), and reformation (1688) brought the British Parliament dominated by city merchants and manufacturers to supreme power, thus hastening the evolution of the British nation and its merchants into industrialists. The English revolution of 1642-1658-1688 gave rise to the flowering of English arts and crafts and to a position of eminence in the seventeenth century Europe. The seeds of the Industrial revolution of 1760 were therefore sown during the period prior ro the English civil war.

The same phenomenon is repeated though at delayed intervals in Holland (overthrown of Spanish rule and establishment of Dutch States General in the late 17th century) the French revolution of 1790's, the German revolution of the early 19th century and the declaration of indepencence by U.S.A., the forced breakup of Japanese feudalism in the late 19th century, the Soviet October 1917 revolution, the Chinese revolution all preceded the dates of the economic take offs.

We would therefore argue that before science could lead to development, a transformation in philosophical, social, political and cultural outlook is essential. The cases of Britain, France, Germany, U.S.A. studied by us are those where these changes took place as a result of internal development. Once they happened they have so transformed the rest of the world that these cannot be repeated, Furthermore a very long time elapsed between the take-off and mass-consumption stages. Such long periods are not available to the developing countries. What could be done?

SCIENCE AND TECHNOLOGY POLICY AND DEVELOPMENT BASED ON SCIENCE AND TECHNOLOGY

Since the last deceds of the 19th century the whole world has been transformed into a single economy. The developed countries depending for the import of raw materials (minerals, agricultural, oil, gas) on the developing countries, who in their turn are dependent on the developed countries for the import of food grains and machine manufactures, machines and capital. This international economic order is highly innocuous, weighted heavily in favour of the developed countries. Since the late sixties the developing countries have been clamouring for a new International Economic Order (NIEO) which may be more equitable. But so far the developed countries have not yielded and are not ready to make any concessions. (For a fuller account see books cited in general Refs.) It is therefore necessary for the developing countries to evolve such policies for science and technology, that a sizeable and self-sustaining stock of manpower essential for development is created within the countries. But at the same time they must also institute reforms within the social, cultural, political and economic spheres which promote the welfare of common people, encourage, promote and sustain scientific oulook among the common people and use science and technology for broad-based, overall development for all. A group of Latin American social scientists, have made a world model which shows that with certain policy changes to be undertaken in the national and international sectors, it is materially feasible to achieve a world free "from underdevelopment, oppression and misery".[1] Nobel laureate economist W.W. Leontief also suggests a input-output model of the world economy which could narrow the gap between the rich and the poor if a system of international economic relations that features a partial disarmament could be arranged.[14] So the situation is not as helpless as some prophets of doom have prospected it to be. With courage and determination to undertake structural changes in social, cultural, political and economic sphere at the national and international levels the whole world could prosper together.

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TABLES

Table 1 from S. Radhakrishna, P. op. cit.

Tables 3-7 from A. Rahman, op. cit.

FIGURES

Figures 1,3-6 from Herrara's, op. cit.

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TABLE I

The Development Gap, by Group of Countries

	Low Income Countries	Lower Income Countries	Upper Middle Income Countries	High Income Countries
1. Mid-1976 Population (in millions)	1341.3	745.4	470.6	1057.0
2. Average Per Capita Income in US$	152	338	1091	4361
3. Average Birth Rate Per 1000 of Population	40	30	36	17
4. Average Death Rate Per 1000 of Population	17	"	10	9
5. Average Life Expectancy	48	61	61	71
6. Average Infant Mortality Rate per 1000 live birth	134	70	82	21
7. Average Literacy Rate	33%	34%	65%	97%
8. Average Per Capita Expenditure on i) Education (US$)	3	10	28	217
ii) Military (")	6	17	31	232
9. ASHA Development Index (growth rate x employment x literacy x life expectancy x birth rate x infant mortality)	43	341	594	10,470

Source : The U.S. and World Development Agenda, 1977.

TABLE 2

Disparities In Economic Development Since Industrial Revolution

Year	Per Capita Developing Countries	GNP (in 1960 US$) Developed Countries
1750	188	182
1900	175	540
1977	355	2739

Source : Ref. 8

TABLE 3

Educational STATISTICS for India

[*Source*: University Grants Commission, New Delhi]

Total Student Enrolment. In 1974–75, 2,366,541 students were enrolled in universities and their constituent and affiliated colleges. This excludes the number enrolled in pre-university and intermediate classes.

The total was made up as follows: undergraduate, 2,075,039; postgraduate, 234,114; research, 17,977; diploma/certificate, 39,411. Total: 2,366,541.

The distribution of the 2,366,541 students by categories of study was as follows: agriculture, 29,293; arts (including oriental learning), 1,056,077; commerce, 389,504; education, 77,179; engineering & technology, 90,685; law, 134,811; medicine, 106,340; sciences, 463,441; veterinary science, 6736; others, 12,475.

The 252,091 postgraduate and research students were distributed by categories of study as follows (the figure in brackets is the number of research students included in the preceding figure): agriculture, 5747 (1169); arts, 139,586 (8084); commerce, 28,326 (565); education, 3795 (325); engineering & technology, 5136 (610); law, 3235 (117); medicine, 8143 (358); science, 55,586 (6463); veterinary science, 860 (205); others, 1677 (81). Total: 252,091 (17,977).

Students from Other Countries. *See* Appendix II.

Degrees Awarded (1973–74). *Agriculture:* BSc (Ag), 4505; MSc(Ag), 1313. *Arts*, BA, 259,051; BA hons., 20,466; MA, 67,621. *Commerce:* BCom 76,242; BCom hons., 6939; MCom, 8869. *Education:* BEd, 60,616; MEd, 2146. *Engineering & technology:* bachelors, 13,491; masters, 1268. *Law:* LLB/BL/BGL, 23,148; LLM/ML, 221. *Medicine:* MB BS, 10,578; MD, 1161; MS, 799. BPharm, 3 MPharm, 114; BDS, 499, MDS, 89; BSc(Nursing) 165; MSc(Nursing), 13. *Science:* BSc, 108,287. BSc hons., 13,614. MSc, 17,122. *Veterinary scien*: BVSc, 998; MVSc, 242.

Doctorate degrees awarded (1974–75) (incluc PhD). (Provisional figures) *Agriculture:* 281. *Art* 1258. *Commerce:* 55. *Education:* 77. *Engineer technology:* 163. *Law:* 5. *Medicine:* 50. *Science* 1515. *Veterinary science:* 60. *Others:* 14. Total 3478.

TABLE 4

STOCK OF SCIENTIFIC AND TECHNICAL PERSONNEL
1950-1977

Category of Personnel	1950	1955	1960	1965	1970	1977 (Estimated)
	Stock at the end of the year (000)					
(a) Engineering & Technology:						
(i) Degree	21.6	37.5	62.2	106.7	185.4	251.9
(ii) Diploma	31.5	46.8	75.0	138.9	244.4	346.7
(b) Science:						
(i) Post-Graduates	16.0	28.0	47.7	85.7	139.2	243.4
(ii) Graduates	60.0	102.9	165.6	261.5	420.0	1182.2
(c) Agriculture:						
(i) Post-Graduates	1.0	2.0	3.7	7.7	13.5	112.7
(ii) Graduates	6.9	11.5	20.2	39.4	42.2	
(d) Medicine:						
(i) Degree	18.0	29.0	41.6	60.6	97.8	174.3
(ii) Licentiate	33.0	35.0	34.0	31.0	27.0	17.0
Total:	188.0	282.7	450.0	731.5	1174.5	2328.2

Source: Cols. (2) to (6) Division of Scientific and Technical Personnel CSIR.

TABLE 5

MANPOWER EMPLOYED IN R & D ESTABLISHMENTS 1976-77

(As on 1st April, 1976)

S. No.	Name of the R&D Estt.	Personnel engaged primarily in R&D activities	Personnel engaged in auxiliary scientific/technical activities	Personnel employed on adm. & other non-technical supporting activities	Total
1.	CSIR	5,649	8,604	5,124	19,377
2.	ICAR	4,811	2,354	10,211	17,376
3.	ICMR	504	380	748	1,632
4.	DAE	3,461	6,491	4,113	14,065
5.	DRDO	4,879	6,074	7,688	18,641
6.	Space	5,165	—	3,505	8,670
7.	Science & Technology	838	951	1,307	3,096
8.	Central Ministries	10,342	13,267	4,771	28,380
9.	Private Sector	9,211	—	4,536	13,747
10.	States	9,245	3,632	9,962	22,839
	Total	54,105	41,753	51,965	147,823

Source: Data compiled by DST.

TABLE 6a

TRENDS IN EXPENDITURE ON RESEARCH, DEVELOPMENT AND RELATED SCIENTIFIC AND TECHNOLOGICAL ACTIVITIES

1948-49 to 1976-77

(Rupees crores)

	1948-49	1950-51	1965-66	1970-71	1975-76	1976-77
(A) Expenditure on R&D						
Central Sector	1.10	4.68	62.45	112.47	287.61	321.73
State Sector	na	na	3.51	12.58	26.73	31.02
Private Sector	na	na	2.43	14.59	42.35	49.50
TOTAL (A)	1.10	4.68	68.39	139.64	356.69	402.25
(B) Expenditure on Related Science & Technology Activities						
Central Sector	na	na	16.67	33.73	36.09	39.76
State Sector	na	na	na	na	5.21	6.12
TOTAL (B)	na	na	16.67	33.73	41.30	45.88
GRAND TOTAL (A&B)	1.10	4.68	85.06	173.37	397.99	448.13

Sources: (i) For data for 1948-49 and 1950-51, Science Policy and Organisation of Scientific Research in India, page 99.
(ii) For data upto 1970-71, Report on Science & Technology, 1970-71 brought out by COST. For subsequent years data compiled by DST.

Note : 1. Data for 1948-49 represents only expenditure of CSIR, ICAR, ICMR and DAE.
2. A number of organisations are mainly engaged in scientific and technological activities such as weather forecasting, geological and geophysical survey, teaching consultancy. In addition they also undertake research for which no separate account is maintained. Their expenditure on research has been estimated

TABLE 6b

EXPENDITURE ON R & D—CENTRAL MINISTRIES

1974-75 to 1976-77

Sl. No.	Name of Ministry	Expenditure on R&D 1974-75	1975-76	1976-77
1	2	3	4	5
1.	Agriculture and Irrigation			
	(a) Agriculture	137.05	153.99	161.09
	(b) Food	50.18	93.43	96.02
	(c) Irrigation	192.35	213.94	301.33
2.	Commerce	69.66	83.82	122.16
3.	Chemicals and Fertilizers	352.73	418.99	465.04
4.	Communications	226.30	422.66	715.74
5.	Defence Production	799.14	850.14	980.46
6.	Education (UGC)	251.00	524.00	545.00
7.	Energy			
	(a) Coal	7.61	16.35	106.56
	(b) Power	47.79	52.49	64.66
8.	Health and Family Welfare	452.75	527.47	586.13
9.	Information and Broadcasting —	9.04	11.48	21.72

TABLE 6c

1	2	3	4	5
10.	Industry and Civil Supplies			
	(a) Heavy Industry	298.39	549.84	750.15
	(b) Industrial Development	41.73	147.46	78.16
11.	Petroleum	225.03	325.08	400.17
12.	Railways	284.00	345.00	320.00
13.	Shipping and Transport	1.74	0.46	0.59
14.	Steel and Mines			
	(a) Steel	42.31	92.20	93.48
	(b) Mines	1271.73	1396.67	1552.91
15.	Tourism and Civil Aviation	91.22	107.71	138.40
16.	Home	11.00	12.24	14.21
17.	Supply	11.77	14.89	14.27
18.	Works and Housing	16.25	23.27	25.47
	TOTAL	4890.77	6383.58	7553.72

Source : Data collected by DST.

TABLE 6d

INTERNATIONAL COMPARISONS OF R & D EFFORTS

Sl. No.	Country	Year	R & D Expenditure as % GNP.	Per Capita R & D Expenditure (US $)	Scientists and Engineers per 1000 of population	Scientists and Engineers engaged on R & D per 1000 of population	S & T personnel deployed on R & D (%)
1.	USA	1974	2.3	158.50	11.90	2.68	22.52
2.	USSR	1975	NA	NA	81.54(1973)	3.72(1973)	4.56(1973)
3.	GERMANY (FRG)	1973	2.1	117.24	18.61	2.97	15.95
4.	UK	1972	2.0	58.79	—	—	—
5.	NETHERLAND	1974	2.0	159.65	56.25	3.92	6.97
6.	JAPAN	1975	2.1	83.46	185.08	4.40	2.40
7.	FRANCE	1974	1.7	91.14	—	—	—
8.	SWEDEN	1973	1.6	101.08	—	—	—
9.	INDIA	1976-77	0.6	0.43	3.80	0.09	2.37

Source: UNESCO Statistical year book 1976, pp. 728-734 & 738-73.

TABLE 7

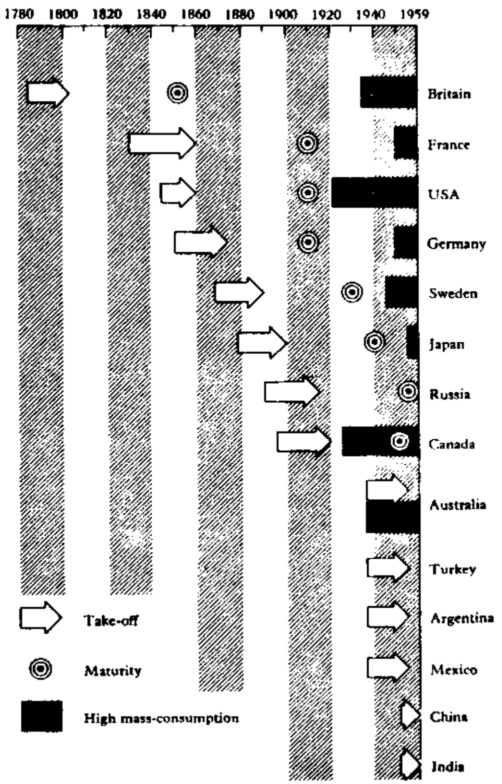


Chart of the stages of economic growth in selected countries. Note that Canada and Australia have entered the stage of high mass-consumption before reaching maturity. [By courtesy of the *Economist*.]

TABLE 8

R&D ORGANISATIONS/INSTITUTIONS IN INDIA
1977-78

A. *Central Sector*

I. *Ministry/Department/Agency*	*No. of institutions*
I. *AGENCIES*	
1. Department of Atomic Energy	7
2. C.S.I.R.	44
3. Department of Science & Technology	19
4. Space	5
5. Defence Research & Development Organisation	31
6. I.C.A.R.	29
7. I.C.M.R.	8
8. Department of Electronics	1
	144
II. *Ministries of Central Government*	
1. Department of Agriculture	17
2. Ministry of Chemical and Fertilizers	8
3. Department of Defence Production	9
4. Department of Coal	6
5. Ministry of Health and Family Welfare	31
6. Ministry of Home Affairs	6
7. Department of Heavy Industry	9
8. Department of Industrial Development	22
9. Ministry of Petroleum	7
10. Department of Steel	7
11. Department of Mines	7
12. Ministry of Tourism and Civil Aviation	6
13. Ministry of Works and Housing	5
14. Other Ministries (Food, Irrigation, Commerce, Power, Coal, Information & Broadcasting, Railway, Shipping, Transport and Supply).	27
	168

Total Centre-Sectors : 144+168=312.

B. *State Sectors*	
1. Andhra	4
2. Assam	3
3. Bihar	5
4. Gujarat	13
5. Haryana	3
6. Himachal Pradesh	3
7. Karnataka	5
8. Kerala	14
9. Madhya Pradesh	7
10. Maharashtra	15
11. Orissa	9
12. Punjab	5
13. Rajasthan	14
14. Tamil Nadu	29
15. Tripura	1
16. Uttar Pradesh	11
17. West Bengal	25
	166
C. *Universities*	
1. Universities	79
2. Agricultural Universities	24
3. Institutions of University status	17
	120
D. *Private Sector* Recognised by DST	348

FIGURE 1

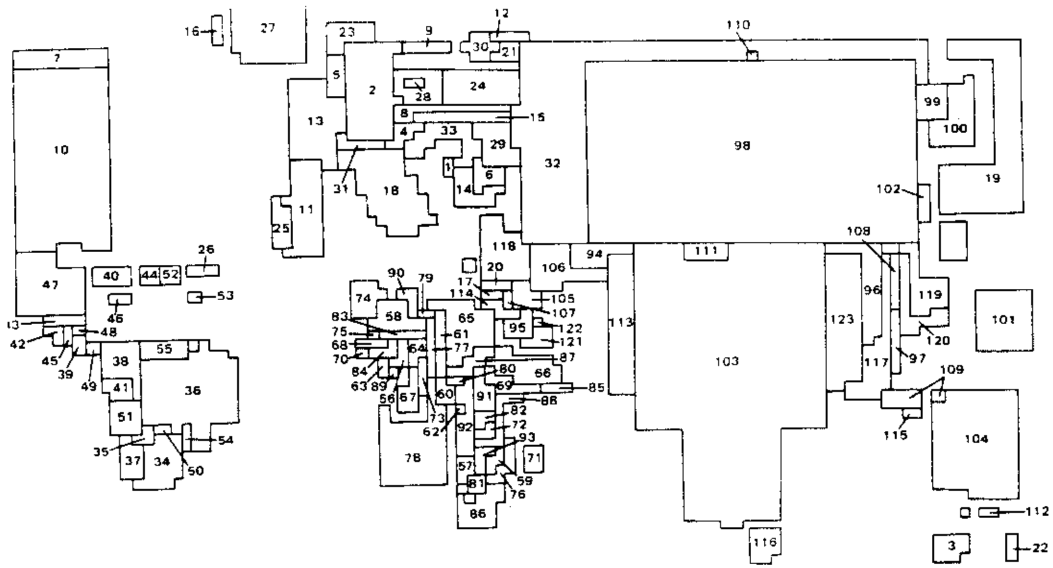


Fig. 1. The world, in which the area of a country is drawn in proportion to its population. The numbers coincide with the following countries:

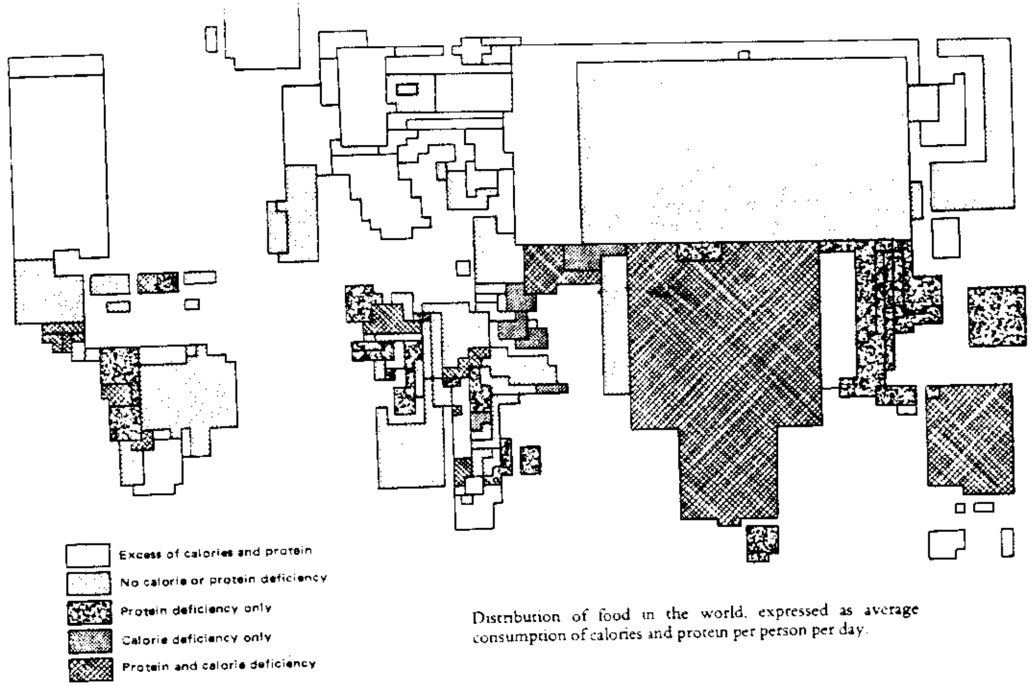
Region 1
1 Albania
2 German Federal Republic
3 Australia
4 Austria
5 Belgium
6 Bulgaria
7 Canada
8 Czechoslovakia
9 Denmark
10 USA
11 Spain
12 Finland
13 France
14 Greece
15 Hungary
16 Ireland
17 Israel
18 Italy
19 Japan
20 Lebanon
21 Norway
22 New Zealand
23 Low Countries
24 Poland
25 Portugal
26 Puerto Rico
27 United Kingdom
28 German Democratic Republic
29 Rumania
30 Sweden
31 Switzerland
32 USSR
33 Yugoslavia

Region 2
34 Argentina
35 Bolivia
36 Brazil
37 Chile
38 Colombia
39 Costa Rica
40 Cuba
41 Ecuador
42 El Salvador
43 Guatemala
44 Haiti
45 Honduras
46 Jamaica
47 Mexico
48 Nicaragua
49 Panama
50 Paraguay
51 Peru
52 Dominican Republic
53 Trinidad and Tobago
54 Uruguay
55 Venezuela

Region 3
56 Upper Volta
57 Angola
58 Algeria
59 Burundi
60 Cameroons
61 Chad
62 Congo
63 Ivory Coast
64 Dahomey
65 Egypt
66 Ethiopia
67 Ghana
68 Guinea
69 Kenya
70 Liberia
71 Madagascar
72 Malawi
73 Mali
74 Morocco
75 Mauritania
76 Mozambique
77 Niger
78 Nigeria
79 Libya
80 Central African Republic
81 Rhodesia
82 Rwanda
83 Senegal
84 Sierra Leone
85 Somalia
86 South Africa
87 Sudan
88 Tanzania
89 Togo
90 Tunis
91 Uganda
92 Zaire
93 Zambia

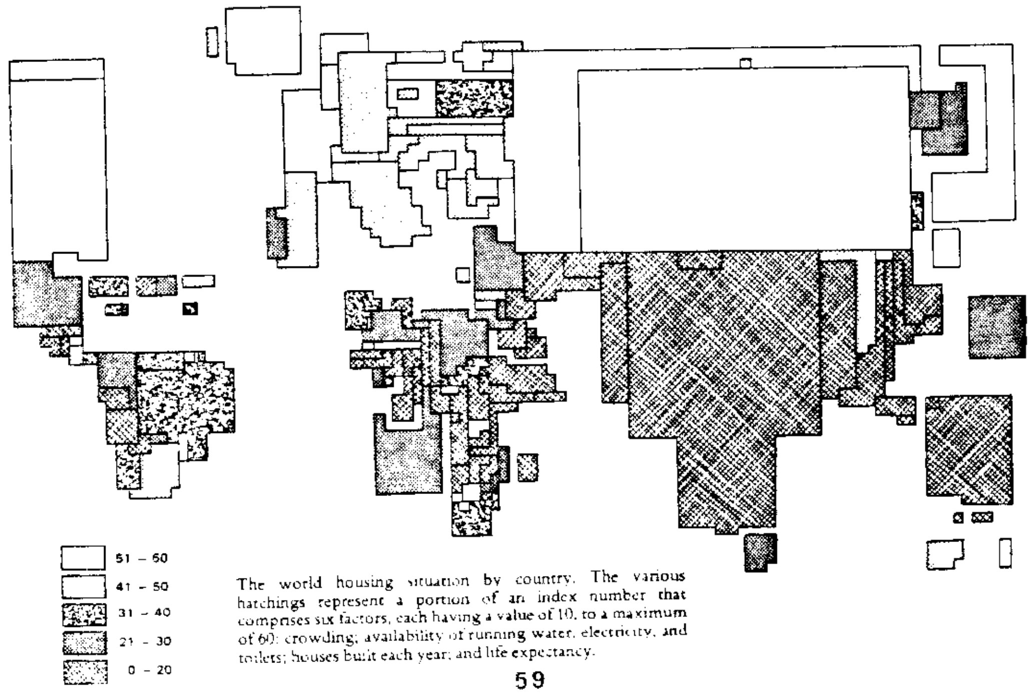
Region 4
94 Afghanistan
95 Saudi Arabia
96 Burma
97 Cambodia
98 People's Republic of China
99 Korea, North
100 Korea, South
101 Philippines
102 Hong Kong
103 India
104 Indonesia
105 Iraq
106 Iran
107 Jordan
108 Laos
109 Malaysia
110 Mongolia
111 Nepal
112 New Guinea
113 Pakistan
114 Syria
115 Singapore
116 Sri Lanka
117 Thailand
118 Turkey
119 Vietnam, North
120 Vietnam, South
121 Yemen
122 Yemen, Democratic
123 Bangladesh

FIGURE 2



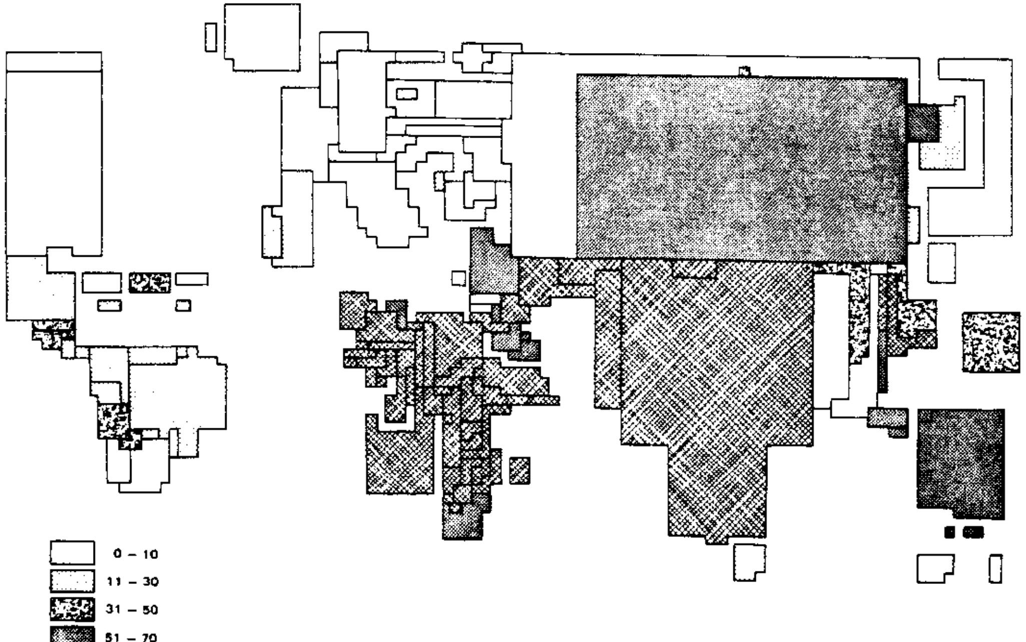
Distribution of food in the world, expressed as average consumption of calories and protein per person per day.

FIGURE 3



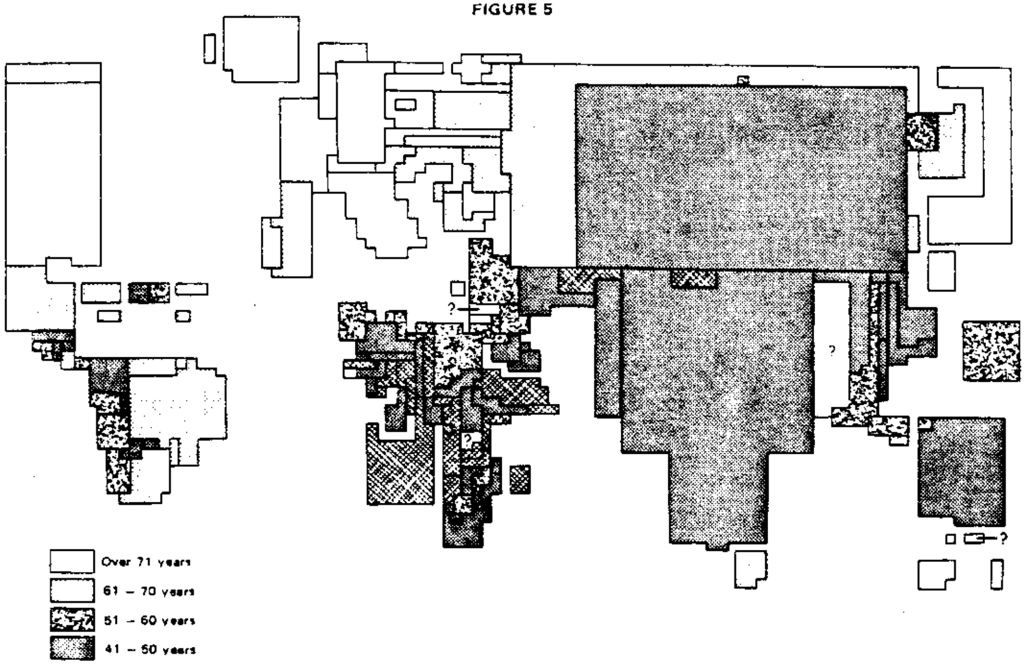
The world housing situation by country. The various hatchings represent a portion of an index number that comprises six factors, each having a value of 10, to a maximum of 60: crowding; availability of running water, electricity, and toilets; houses built each year; and life expectancy.

FIGURE 4



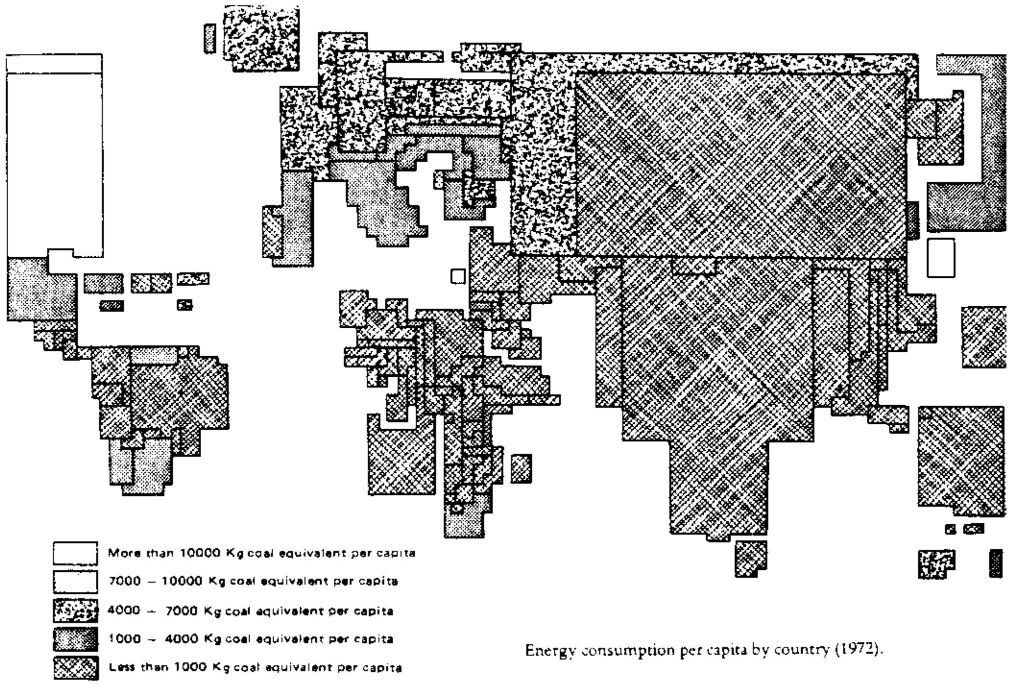
Percent of illiterates in population aged 15 years and over.

FIGURE 5



Life expectancy at birth by country.

FIGURE 6



Energy consumption per capita by country (1972).

A PLEA FOR HELP FOR SCIENCE IN THE DEVELOPING WORLD

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In his thought-provoking book "Science Development: Towards the Building of Science in Less Developed Countries" Moravcsik entreats scientists from such regions of the world "to become more vocal about their science development needs". The plea for action on the problems that beset the development of science in less developed countries (LDCs) must necessarily be directed to both advanced countries (ACs) and LDCs. This article seeks to draw the attention of ACs to some of the pressing problems. A companion article "For how long should a LDC remain a LDC?" calls upon scientists, governments and the public in LDCs to rise up and do something about their plight.

It is inevitable that an article like this can not be anything, but essentially a repetition of what the Zimans, Salams, Moravcsiks and countless others have already written. Indeed, I calculate that had a fraction of the scientists and policy makers in both ACs and LDCs listened to these people, LDCs would cease to be LDCs in about another thirty years or so. This calculation is based on the fact that there was only a 50-year gap between the time Japan sent her first generation of scientists to be trained abroad and the time it started to developed into one of the most important scientific communities in the world (Moravcsik, 1975, p.50). And the first pleas for help to uplift science in the developing world were made more than twenty years ago!

There is no doubt that science in LDs can not achieve its aim of modernizing its society if the scientists continue in their present state of isolation. Several pleas have gone out to scientists and governments in ACs to support and strengthen the work of such institutions as the International Centre for Theoretical Physics in Trieste (Salam 1970, Ziman 1971, Amuzu 1980). Moravcsik (1975) pointed out that the Centre is specialized (though this is changing rapidly) and relatively small (in relation to the number of scientists it set up to cater for) and that there is the need to build many similar institutions in other fields. It is very sad that in the five years I have been associated with the Centre, the only apparent answer to this plea (to me, at least) is a progressively tighter control on the funds available for its programmes. Abdus Salam, the Centre's director had hoped that since every good university is an international centre of learning, institutions with the affluence and prestige of Brown, Harvard, Princeton, MIT, Rochester, Stony Brook, Cambridge, All Souls, Rockefeller University, New York State University, the Imperial College in London and others would seriously consider the establishment of associate schemes which would bring promising and young scientists from LDCs to their institutions for a period of research (Salam 1966, 1968). Indeed the UN's World Plan of Action for the Application of Science and Technology to Development made the same point: "Universities and institutes in developed countries should increase facilities for promising young scientists from developing countries to spend short periods at such centres while retaining their appointments in their own countries." However, more than fifteen years have passed and it has become more difficult now than then for young faculty members from LDCs to obtain such positions even in their "parent" institutions in ACs. With the persistence with which several writers have tried to obtain a change in attitude of research supervisors, examinors and science advisors in ACs towards their wards from LDCs (Zahlan 1969; Ziman 1969, 1973; Moravcsik 1975) one would have hoped that "parent" institutions in the ACs would welcome the opportunity to, as it were, re-educate the promising young man from that backward third world country whom they had helped, howbeit unwittingly, to grow to believe that the only science worthy of his attention is in "the highly contrived and grossly extravagant pursuit of artificial phenomena at high energies or low temperatures""

But isolation may not be the greatest obstacle to science development in LDCs. Indeed it becomes a problem after the young scientists from a backward country had received his research degree from abroad. What about the period preceding his departure abroad? Some of the problems of science education in the LDCs find root in the fact that pupils in most LDCs do not receive the stimulation of an environment with an established scientific tradition. As a result they grow up regarding science as a subject brought in from outside their world, and therefore inclined to rely on textbooks. This is even much more so when they see in their text, for example, pictures of European plants and animals rather those which they know in Africa or Asia. Burkhardt (1966) has pointed out that there are programmes of UNESCO in progress to find the best approach to scientific background and urged that these activities of UNESCO should be enlarged and intensified. It is still fashionable, however, for aid-giving agencies to donate large quantities of books to the libraries of universities in LDCs amid much fanfare while the secondary schools are neglected. In my own country, for example, it is not uncommon to find teachers from secondary schools combing the university science departments in search of borrowable equipment.

Many scholarship-awarding agencies in ACs still offer scholarship to young students from LDCs to do undergraduate work abroad. There are several reasons why this cannot be a good practice. As pointed out by Burkhardt, for those LDCs which already have full universities, the capacities of these universities are far from being exhausted. It is the best students, whose presence in their home universities can set the standards for their colleagues, who go abroad on these scholarships. Several of them, with the added handicap of a foreign language, find the competition too stiff and may, in fact, contribute to the widely held prejudice that students from LDCs are inferior. Of those that make it, a large percentage simply refuse to return home. Those that do return tend to expect too much of a developing system and, except the strong-willed, many cannot resist the "brain drain" magnet. In the case of postgraduate scholarships there are good reasons for sending students from LDCs abroad since most universities in LDCs are yet to set up viable graduate programmes. However, since this practice deprives the science departments in LDCs of their best junior workers and hence restricts research activities, it will be prudent to first look into the possibility of sending these students to other LDCs where facilities for their training may exist. Another suggestion which must be seriously considered is that graduate students from ACs should be awarded scholarships to do research work in LDCs. In Ghana, for example, students from ACs study for the M.A. degree in several fields. Why cannot science research students also come and engage in such projects as, for example, the upwelling of the tropical waters - a subject of some use to the tuna vessels from their countries? Indeed Ziman (1973) lists several other topics for worthwhile physics research in LDCs: thunderstorms, the ionosphere, geomagnetism. strange structures, archaelogical objects, craft processes, building and medical devices. The argument against such ventures is that adequate supervision may not be easy to arrange. But, in fact, in a few cases it may just happen that there is, on the faculty, an experienced researcher from a developed country who may be interested in such a project. It may not be true to say that it costs nothing, but the possibility of such a coincidence should be at least investigated.

It has been suggested that one of the major weaknesses of scientists in LDCs is their inability to act as channels of communication for important technological breakthroughs between ACs and their communities. Zahlan (1969) envisages a situation where a college science teacher who is unable to do research reads semi-technical reports on such things as improved techniques

in water prospecting, protein production from petroleum, power production or electronics and diffuses such information within his immediate community. Although this is as it should be, the gloom will not lift if the major scientific journals and magazines continue to be aimed at scientists in ACs so that it remains difficult for those in LDCs to gain access to and publish in them. Some journal still require publication charges which must be paid in hard currency. Subscription charges must also be paid in foreign currency, and unless extra charges are paid for air-mail delivery, some may arrive several months after publication. A possible remedy that has been suggested is the local production of satellite editions of the primary journals on a regional basis (Moravcsik 1975). Journal editors, however, stand in the way of this idea. They fear that such satellite copies may be reimported and thus undermine subscriptions. Since journal editors are scientists who may basically be favourably disposed towards moves to help their colleagues in LDCs, we can only hope that this attitude will change quickly. Several other measures designed to close the communication gap that isolates and hampers the performance of scientists in LDCs have been suggested. Among these are the improvements of the system of preprint distribution which "favours the Nobel laureates at large institutions", and the use of microfiche. Scientists in ACs must, through their professional societies which sponsor journals, work to remove the obstacles in the way of the implementation of these suggestions. Several scientists in LDCs, after their return home from training in institutions in ACs, make an effort to retain their membership of such societies as the Institute of Physics. This would allow them to receive, in this particular case, issues of the very useful Physics Bulletin. This determination is usually frustrated by the requirement that, although on account of their living so far away they cannot take advantage of some of the other priviliges of membership, their subscription fees escalate almost as fast as those of resident members! In some cases problems of exchange control regulations are not handled with the needed patience and tact so that membership and the vital link are all too easily lost to the scientists in LDCs. Again, the plea is to these societies to spare a thought for the need to bend backwards a little in order to contribute to the development of science in the developing world.

Scientists aid to LDCs also requires a new approach. There are various organizations in ACs which give aid to LDCs. However, the great potential of their programmes in speeding up the development of science in LDCs remains largely unutilized due to several weaknesses of their approach. For example, their aids tend to support programmes that promise short-term gains and are oriented towards technology. Since science development is a slow process aid-giving agencies must show a willingness to wait for a decade in order to see real results. Scientists in ACs must devote an increasingly greater amount of their time to issues of the administration of scientific assistance. This will help to remove the bottleneck of bureaucracy that soon settles in with an administrative staff that is largely non-scientific and prevents scientific aid from reaching scientific communities in LDCs.

It is not possible to discuss all the difficulties that beset science development in LDCs in an article like this. For one thing, it has to be kept to a reasonable length to ensure consideration for publication! For another, I do not have access to most of the excellent articles that have been written on the subject for reasons already discussed. However, one should not end without acknowledging the heroic efforts of several individuals and organizations in ACs. Recently a Regional College on the Theory of Condensed Matter was held in Accra, Ghana. It was under the auspices of the Centre in Trieste with funds provided by the UN Interim Fund for Science and Technology for Development. The aim of this College was to provide instructions at a more elementary level to potential visitors to Trieste so as to make their attendance at the Trieste courses more beneficial. The important point that must be made here is the tenacity of purpose which led to the realization of the regional college idea which was first suggested, as far as I know, as far back as 1971 in the wake of the substantial successes of the Winter College in Trieste (see Ziman 1971, p. 354). For ten years the idea was kept alive until its final realization. I believe that this is what should be with all the issues that concern science development in LDCs.

In their recent manifesto against hunger and under-development fifty-three Nobel Prize laureates had this to say: "If the news media and those who have honoured us will only listen to what we are saying; if they will only take notice of what we are doing, and what many others with the same ideas are doing; if only people are told what is happening, then the world's dark future, which now seems to threaten everyone in it, may be changed. But only if we take action. Now is the time to act, now is the time to create, now is the time for us to live in a way that will give life to others." (emphases mine) I like to believe that a more eloquent appeal to ACs on behalf of science development in LDCs cannot be found than in these words although they were written on behalf of hunger and under-development. Yet I do not err, for the link between hunger and development and a lack of the scientific touch requires no justification!

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A F R I C A

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When I was invited to give a talk on the acitvities of Physics in Africa I regarded this as a very big task because of the size of the material I have to cover. In addition to this, I saw Africa as a developing continent in which Physics is yet to play a very active role. As a developing land, there are so many problems to be looked at in the context of Physics. In this light I decided to change the topic from the Activitites of Physics in Africa to Africa, Physics and Development. This is by no means a big topic to be digested in an hour, nevertheless I have tried to be as brief as possible.

Development of a system, either physical, social or spiritual arises out of attempts to solve or find solutions to problems arising there of. In this regard I am discussing the development of Africa from a problematic point of view.

Africa as seen from Fig.1 has been divided into three parts - the Arab Africa which includes Morocco, Tunisia, Sudan, Egypt, Libya and Algeria; Tropical Africa generally termed Africa south of the Sahara and the Republic of South Africa. My discussion is centred around Tropical Africa.

Tropical Africa occupies an area of 20.8 million squared kilometres about two-thirds of African area and has a population of 350 million, about seventy percent of the total African population. Of this population about seventy percent live in the rural area. The rate of growth of population is about 2.7 percent with a life expectancy of about 55 years.

The climate and vegetation of Tropical Africa as seen in Fig.2 starts from Desert in-land where there is very little vegetational cover or none at all with an annual rainfall of less than 25 millimetres with high daily temperature greater than 32°C.

From the desert comes the semi-desert where the annual rainfall is below 100 millimetres with short grass interspersed with short trees. Its daily

temperature is about 32°C. Following the semi-desert is the wooded savannah where the trees are short and the grass tall. The annual rainfall is also between 100 and 200 millimetres. This is the largest vegetational cover in the tropica. In the forest region the annual rainfall is greater than 200 millimetres. The vegetational cover is thick forest to open forest with tall trees. There are a lot of human activities in this region. There is no line of dichotomy between one natural region and the next, one region normally fades gradually into the next.

The geology of Tropical Africa is such that she is very rich in minerals and other natural resources such as swift rivers for hydroelectric power generation oil and so on.

GENERAL VIEW OF THE ECONOMY

The G.N.P. of Tropical Africa as at 1980 was two hundred and sixty dollars of which about thirty countries fall in this group. However, countries like Nigeria, Ivory Coast, Gabon, Ghana, Lesotho, Cameroons, Kenya, Zimbabwe have G.N.P. greater than three hundred and seventy (370)dollars and therefore are termed developing (see Fig.3).

The G.D.P. of Africa as shown from Fig.3 reveals that thirteen countries have less han $100, four have greater than $500 and the rest around $194. Of these G.D.P.'s manufactured value added accounted for less than 8 percent in 19 countries, between 8% and 12% in 9 countries and betwwen 12% and 15% in 6 countries and more than 15% in three countries.

The rate of growth of the economy of Tropical Africa is rather sluggish and in certain countries there is rather a negative growth rate and one would expect slow economic development if not no growth at all.

The exports of Africa include oil, timber, gold, bauxite, diamonds, uranium, cocoa, coffee, sisal, skins and hides, manganese, iron ore, tungsten, vanadium, tin, columbite and so on.

Her imports include agricultural machines, transport and communication equipment, fertilizers, textile and clothing, books and news prints.

Both the imports and exports are not exhaustive. With a wide variety of highly expensive exports one would have expected the economy of Tropical Africa to be good. The result is that there is a negative turn of events in economy of most states.

I can not stop examinining the development of Tropical Africa without looking at the factors leading to zero or slow rate of development under nine groups of problems:

1. Energy 2. Health 3. Education 4. Agriculture
5. Technology transfer and adaptation 6. Enviromental problems
7. Social 8. Political 9. Economic.

These problems may overlap one another and one problem may lead to anothe In short they are causally related problems. Nonetheless each problem stands out uniquely. It is in these problems that the activity of Physics is well defined.

1. Energy

There are three main sources of energy in Tropical Africa - fossil fuel, wood and electricity. Most Africans depend on wood and the fossil fuel as their main sources of energy. Electricity is a thing for the urban dwellers. Few countries in Tropical Africa - Nigeria, Gabon, Ivory Coast and Angola are oil exporters, the rest all import oil eventhough there are deposits of oil ready for exploitation. In addition to this, energy from wood is widely used for heating and cooking purposes. This wide use of wood coupled with population growth have increased the activity of man destroying trees. In the Sahelian and sub-Sahelian region, this is destroying the vegetation cover and aiding the expansion of the Sahara. The Sahara is really expanding and countries bordering this desert have a big environmental problem. There should be an alternative to this great demand for wood in this region as fuel and elsewhere when the price of oil started increasing, the great demand for this fuel resulted in huge trade deficits thus slowing down economic growth. This is a big trouble - Economic problem. These two problems in energy led many countries like Senegal Niger, Mali and Central African Republic to start seriously on solar energy harnessing. Physicists are busy working in laboratories in Senegal on solar energy. Countries with oil deposits are now going an all out exploitation using geophysicists to tap this to easy their economic constraints. Biomass fuel and nuclear power are also on the top list and countries like Nigeria are dreaming on nuclear. As at now there are solar powered T.V. sets and cookers being used in Mali and Niger.

In countries where hydroelectric-power is abundant like Ghana, Cameroons, Zambia and Ivory Coast efforts are being made to utilize it effectively.

In 1981 there was an energy Conference in Kenya attended by scientists and technologists including African physicists to find an answer to the global energy crisis, more especially in Africa.

2. Health

The life expectancy in Tropical Africa is about 55 years compared to 72 years in Europe and America. Most people die from diseases and the argument is that there are not adequate hospitals and doctors. This is looking at the curative part of medicine. The other side of the question is preventive medicine. Research conducted reveals that most diseases are either water borne or insects borne. Cholera, bilharzia, worms of various kind and so on are water borne diseases. Fever, onchocersiasis, sleeping sickness and so on are insects borne diseases. To get rid of these insects chemicals have been used but the problems of pollution and the insects developing immunity to these chemicals are likely possibilities; moreover, spraying of breeding grounds of these insects may not cover every area.

The side effects of malaria curing drugs like chloroquine are so dangerous that it is even not advisable to administer such a drug to a patient. The only solution to these problems is the use of nuclear radiation in sterilizing the males of the insects and thereby rendering all eggs laid by the female unfertile thsus killing them softly in great numbers. This requires medical physicists and a research reactor. In Africa, Zaire and Madagascar has nuclear reactors but have not developed seriously in this field. There are a lot to be played in the health needs of the people by physicists.

Water borne diseases are being fought on a wider scale due to the tapping of underground water for the rural people as a result of extensive geophysical studies of the area. Presently some areas in the Sahelian regions enjoy good drinking water from wells sunk to underground water deposits.

3. Education

In Tropical Africa about 10 per cent of her population can read and write and a small percentage has even heard of Physics during the early 1960s. There is the need for Physics Education.

40 per cent of the African population is the teenage group of which 45 per cent are in school and about 30 per cent of the school-going study science at the college level with a small percentage reading Physics at the University level. This is a low turn out of physicists and therefore research groups are very small in size ranging from one man to six. Despite this problem of size physicists are actively engaged in teaching at the high-schools, colleges and universities in addition to their normal research work.

Education is a problem in Tropical Africa because the high rate of illeteracy makes communication difficult and lack of physics education has made the minds of the Africans dogmatic and conservative. Nature has tamed the African and it is through physics education that few have realised the easiness in the taming of nature.

4. Agriculture

About 90 per cent of the African rural dwellers are engaged in agriculture, using the most fundamental implements like hoe, cutlass, animal and human power for their production. In animal husbandry even though some give a lot of attention to their produce, yet natural course of their development is left untampered with. These accounts for low yield which is insufficient to meet the consuming populace.

There are factors leading to these problems of low productivity.

1) Fluctuating weather conditions resulting in a great loss of crops and animals. A case in point is the 1970's drought when well over 2 million cattle died of hunger and thirst and most crops planted in this period also died as a result of the drought.
2) Animals and crops are irresistible to pests and diseases.
3) Insufficient soil data has made mechanized farming attempted by some states futile. Information about the soil helps in the adoption of the right method of irrigation and ploughing and the type of machinery needed and even crops to be cultivated on the land.
4) Poor storage facilities allows a greater portion of the already low produced items get spoiled within a short period after harvest.
5) Lack of capital to buy modern farming equipment and machinery for increased production.

These and other problems of agriculture are being solved or can be solved by the use of physicists.

Physicists of the weather and the atmosphere are busy working thoughout the Sahara collecting enough data for weather predictions with their headquarters in Dakar. Some are also busy working on underground water exploration as geophysicists and others in hydraulics finding means of storing rain water during the rain season for irrigation.

In addition to this area, physicists are working on soils to collect enough physical data for supply in conjunction with those in the hydraulic section to agricultural experts for improving production along scientific lines.

Moreover, research are going on in Ghana, Kenya, Zaire, Madagascar on hybriding the local crops and pests resistance, using radiation. This will

increase the quality of the fruits, of the crops and thus storage will be quite lengthy.

5. Technology Transfer and Development of Indigeneous Technology

This is a specialized topic of its own, nevertheless I shall try to treat it rather superficially.

Before the advent of colonization, most cultures in Africa had some form of technology which was labour intensive. For example, the Akans of Ghana and Kikuyus of Kenya had weaving technology. The Ifes of Nigeria and Benin Republics had metal technology and advanced art. The Tuaregs of the Sahara had exploration and tapping of underground water techniques. Colonization came in with advanced technology based on machines thus urged out the less developed indigeneous technology. After independence most states opted for the importation of this technology. It was transferred alright but most of the transfer is based on import-substitution; moreover, the products are sub-standard to compete with those from the developed world.

This problem could be due either to managerial incompetence or to adaptation and to which I choose the latter. Adaptation of this technology transfer stems from the fact that no research was conducted into local materials as substitutes to feed the manufacturing industry. Then again indigeneous technology could be greatly improved by importation of technology which is similar in line with the former. These problems could be solved by intensive research by physicists on materials. Wood physicists are working on finding new wood species for other works. This is very active in Ghana, Ivory Coast, Gabon and Zaire. Serious research is now being conducted into building materials and other industrial materials through research centres in most countries in Africa.

6. Environmental Problem

The headache of Africa is the expansion of the Sahara desert claiming about 650,000 square kilometres in the last fifty years and it is fast expanding.

The increase in population in the areas bordering this monstrous vegetation has called for deforestation of the area due to human activity. Overgrazing of the grass in this sub-Sahelian region by animals is also another contributing factor. These factors coupled with the decline in the rainfall in this area have resulted in the expansion of the Sahara Desert. Nature has to be tamed and since the beginning of the mid-1970's countries bordering the Sahara in a joint programme have started afforestation project using physicists, biologists and other scientific personnel. In addition to this, tapped underground water is being used even to irrigate certain dry parts of the desert. In 1980 a college on the Physics of Desert was held at the International Centre for Theoretical Physics and delegates from developing countries attended. The next cause of environmental problem is the creation of artificial lakes as a result of dams across rivers for the production of hydro-electric power. These lakes have become breeding grounds for mosquitoes, simulium flies, tsetse flies and so on which threaten the lives of the inhabitants around the lakes. As I have already discussed the use of chemicals may pollute the rivers so seriously to disturb the ecosytem in the lakes. The only alternative is the use of nuclear radiation.

Environmental problem in the disposal of human wastes and others is also of primary concern but from technology developed elsewhere this could be used for biomass source of energy and this needs serious attention of physicists interested in energy.

Another environmental problem worth looking at is pollution of streams and rivers around the mining areas in Tropical Africa.

7. Economic Problems

I am not an economic expert but I see the problems of the African economy as due to

1. Poor balance of payment due to the importation exceeding exportation in monetary value. This could be due to the fact that most of our exports are raw materials and therefore the prices determined by the buyer. One typical example is the International Cocoa Agreement which allows the exporter to bargain for a minimum price for cocoa for a certain period of time. Imported goods, on the other hand, have their price fixed by the seller since these products are completely finished.
2. Our industries are mostly import-substitutes; as already discussed, attempts have to be made to find local substitutes.
3. Lack of scientific impetus on productivity on our farms and indigeneous technology.
4. Other problems could be due to lack of proper planning based on science and technology, social behaviour of the people and lack of political direction.

Even though physicists have started playing an active role in showing some of these problems there is a lot to be done.

Physicists in Africa are serving on the following Committees of the Organization of African Unity (OAU):

1. Inter-African Bureau for Soils based in Bangui, Central African Republic.
2. Inter-African Committee on Solar Energy based in Dakar, Senegal.
3. Inter-African Committee on Earth Sciences and Geodesy.
4. Inter-African Committee on Geology and Mineralogy.
5. Inter-African Committee on Natural Resources.

All the above are under the Scientific Technical Research Commission with its general headquarters in Lagos, Nigeria.

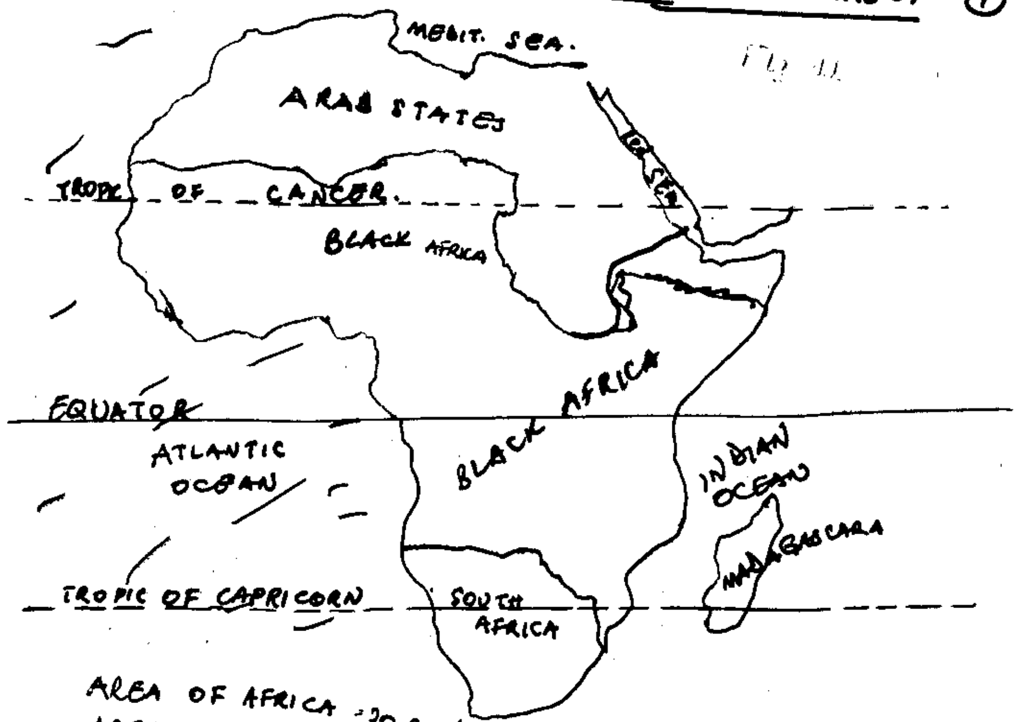
There are nevertheless problems of the African physicist.

1. Isolation:- Interaction among us is very small and as such researches going on elsewhere are not known by others. This normally frustrates African physicists who may be working on a problem that has been solved elsewhere. To reduce this isolation a resolution was adopted ar the end of a Regional College on the theory of condensed matter, in Accra, Ghana, in January 1982 for the establishment of an African Centre for Physics and Technology where Physicists from Africa could meet periodically for either symposia, seminars and workshops.
2. The African physicist has not played an innovative role in the national development on a wide scale. This could be due to lack of science and technology policy as the basis for national development. This is a battle to be fought for and won. Even though the African physicist has not been recognized by the African society as contributing immensely to development it is my conviction that in the fields of health, education, environment, social, political and economic development we have done a lot. The only problem is to translate most researches done and left in the archives to practical use.
3. Finance - Very little money is voted for fundamental research and so equipment are not readily obtained when the need arises.

Fig.1a

FIG 1

AFRICA PHYSICS AND DEVELOPMENT ①



AREA OF AFRICA = 30.3×10^6 km^2
AREA OF BLACK AFRICA = 20.8×10^6 km^2
Population of Africa = 456.0×10^6
Population of Black Africa = 350×10^6
Number of States in Black Africa = 45 all independent.
Number of least developed states in Black Africa 34.
Population growth rate 2.7%

Fig.1b

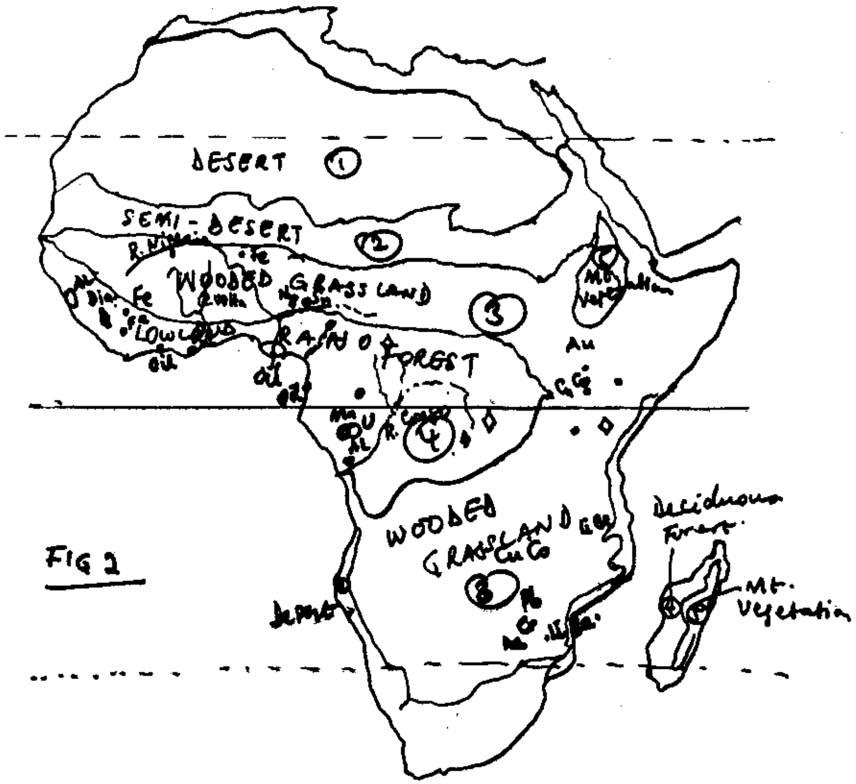


FIG 2

① DESERT: Annual Rainfall < 25mm. Mean daily temp > 32°C. Vegetation Cover – nothing. Deposits of oil in Mali and Uranium in Chad.

② Semi Desert: Rainfall between 25mm and 100mm. Daily temp around 32°C. Vegetation Cover: Short Grass with Scattered trees. Economic activity: Livestock but drought in 1973 and then on ~~[illegible]~~ threatened this activity. Very little farming on land.

③ Wooded Grassland: Rainfall between 100 and 200. Daily temp. around 30°C. Vegetation Cover: Tall grass with trees. Economic activity: Livestock and farming and some minerals

④ Lowland Rainforest: Rainfall greater than 200mm. Daily temp around 28°C. Vegetation Cover: Thick forest to Open forest with tall trees. Economic activity: Farming Cash Crops, Lumbering, mining of oil and minerals, has high density of Population.

(5) Mountain Vegetation Rainfall greater 300mm. Daily temp below 20°C. Vegetation Cover: Scattered trees to no cover. Negligible economic activity

T U R K E Y

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I. INTRODUCTION

I would like to thank the organizers of the "Physics and Development" programme for the opportunity to give this talk on Turkey. The name of this programme is so chosen problably because we are physicists and we have to narrow down the subject of discussion to be more effective. But I think the issue is "Science and Technology for Development". Although there is some discussion on the actual role of science in development, there is no doubt that the "basic" scientific research has given a new and unprecedented dimension to technolgy and is thus vitally linked to development. I think more research is needed on the interrelation of science, technology and development as well as on the economical, social and cultural reasons that led to the present state of international economic order. Instead of going into the discussion of these interesting points I would like to refer you to some earlier works provided at least some of the answers [1-5].

Despite of all the previous efforts, apparently little has been accomplished. And it seems, at least at present, that neither the UN system nor the advanced countries are really interested in the problems of science and technology development in less developed countries. The so called Third World Countries must work together and formulate joint institutions and projects among themselves. The rhetoric of underdevelopment should be converted into a serious action programme. It is important to realize that we must have science first to be able to use it in development. The problem in many developing countries is the establishment of science rather than the proper use of it. Thus, a special emphasis is given in this report to the problems of physics in developing countries and some remedial actions are proposed following the resolution of an international seminar recently held in Istanbul [5]. The Turkish situation is summarized only very briefly.

II. TURKEY

The contemporary science and technology started in Turkey with the establishment of the young republic (1923). A productive and sustained research activity in physics, as in other sciences, began with the university reform in 1933. The development of an industry based on modern technology and an agricultural reform took place in the same period. The state economic enterprises which are established then still form the backbone of the Turkish industry. Another cornerstone in the development of science and technology had been the 1961 constitution which marked the beginning of a new era. The State Planning Organization (SPO) and the Scientific and Technical Research Council of Turkey (TUBITAK) were established in that period. The five year plans prepared by SPO contain sections stating science and technology policies. TUBITAK is charged to implement the state policy and to support the scientific and technical research activities.

Turkey has a rather low GNP per capita on the European scale (1447 US$ in 1979). Research and development has a very modest share (0.2% of GNP in 1979) in total expenditures. In all Rand D, the basic sciences, and in turn physics, is getting an even smaller shere. In recent years, this share, contrary to the expectations, is getting smaller.

Research on physics is presently carried out in Turkey at about 20 institutions which consist of universities and government research organizations. The total number of Ph.D. physicists is estimated to be about 240. Practically no physics research is carried out in Turkish industry. The output of the government research organizations, on the other hand, constitutes only about 10% of the total "national" publications. This indicates that proper physics research in Turkey is taking place mainly in universities. There are presently 19 universities. A number of these universities are newly established and are living through the building up stage. Some do not even have physics chairs or departments. The newly established (1982) "Higher Education Organization" (by a recent law) is reorganizing almost every aspect of higher education in Turkey. The positive or negative effects of this work is yet to be seen.

In the following, I would like to point out some of the problems we are facing in rather general terms as I believe these have a universal character. The problems and proposed remedial actions are taken and rephrased from the resolution of the Istambul meeting (Ref.5 p.7).

III. THE PROBLEMS

1. To different degrees in each developing country and indeed in some developed countries there is a shortage of pupils, reasonably trained in experimental physics, entering universities from secondary schools.

a) The lack of experimental facilities in secondary schools both in terms of laboratories and in equipment for teaching experimental physics.
b) A shortage of well trained teachers in experimental physics.
c) Within the physics profession itself, the view that teaching is an inferior occupation to research. Although this applies particularly in universities and Research Institutes, it reflects into schools beaause it leads to a supply of inferior teachers (failed would be researchers) and so to a supply of poorer pupils to universities (b and c create a "feed-back" situation).

2. There are similar set of difficulties in universities arising largely through a shortage of funds.

a) Poor and inadequate experimental facilities both for research and teaching, the less developed the country the more important the lack of teaching facilities becomes.
b) Where physics research is being pursued, be it in Universities or Research Institutes, it is usually in small groups or by individuals working often in isolation. There are a few notable exceptions to this point, but in general the groups are below a 'threshold' size which enables them to produce work which approaches accepted standards of international recognition.

3. The physics programmes in each developing country, both in teaching and research and whether in Universities or Research Institutes, are limited by restrictions in funds in some instances very severely. Thus:

a) Budgets may cover salaries and maintenace of building but do not cover the simple running costs of equipment, its maintenance and renewal. Rarely do they permit the purchase of new major items of equipment without severe and prolonged struggles.
b) Artificial restrictions occur also due to currency regulations, rigid customs formalities and bureaucracy.
c) Worshops for the construction and maintenance of experimental equipment are too often very poor.
d) Access to adequate computing facilities is very limited.

4. Difficulties of these kinds in some of the developing countries result from an apparent lack of an overall policy reasonably favourable to physics. They also arise from the lack of a large enough and mature enough body of physicists themselves who can influence those policies and society. They also arise from an attitude in society which regards money spent on physics research as a luxury andwwhen it is so spent demands a very short term pay-off.

5. A natural result of these difficulties compounded together is that there are some cells of good theoretical physics distributed in developing countries but the schools of experimental physics which one would expect to find associated with them tend to be weak and in too many instances non-existent.

IV. SOME REMEDIAL ACTIONS

6. These problems cannot be solved quickly but they can be tackled by a systematic approach. One must also bear in mind the economic difficulties in each developing country which tend to restrict expenditure on the basic physical sciences. This factor alone points to the need for international cooperation with each country building on its particular strengths, but of necessity relying on other countries for access to experimental facilities.

7. The crucial areas are those of the University Departments and the Research Institutes. If the level of tertiary physics teaching, particulary experimental physics, and be raised, it will reflect into secondary schools giving them better qualified teachers. This in turn will produce a better flow of pupils properly instructed in experimental physics going to Universities.

8. The professional organizations can help in alleviating the effects of these problems and the following recommendations are made:

i) There are many exchange agreements and arrangemnts already in existence which are not used in the full. This situation should be rectified, one way is by more publicity about exchange schemes in journals.

There is too an obvious tendency for physicists to go to the main countries. Yet in the developing countries there are often groups or laboratories with something real to offer. One must attempt to stimulate European Scientists to visit the developing countries. One way is to collect and publicise information on the state of physics in these countries (e.g. periodic status reports) via the national physical societies so that people become aware of what is going on, to ask physicists who have ahd experiences in such visits to communicate their experience and knowledge of the exchange schemes and publicise it so that others can be encouraged.

ii) A continuing series of Summer Schools in the developing countries should be instituted. The subjects should be chosen to meet the needs of the groups of physicists active in those countries. Such schools should be coordinate with similar activities already in progress, e.g. those of I.C.T.P., I.C.S.U., and I.U.P.A.P. By siting them in developing countries, these schools should become part of the advanced education of young physicists there. They should be arranged with a careful consideration of the possibilities of continuing collaboration between the visiting lecturers and individual groups within the host country. The possibility should also be borne in mind of the evolution of regional centres (see V below) from them. UNESCO could be approached to assist in funding the summer schools.

iii) The participants of scientists from developing countries in professional organization boards of committees and also advising committees in the more developed countries. The idea is to give come public recognition to able and deserving physicists often fighting a tough battle in a national environment where this form of recognition would be most helpful.

The possibility of finding funds to be used to implement the participation of physicists from developing countries in the boards and committees referred to above should be explored.

iv) An effort should be made to create a climate of opinion on questions outside the power of decision of the professional organizations which nevertheless concern physicists. Circulation of papers stating the organizational views whenever occasion arises should help toc reate an awarness (or a healthy discomfort) and perhaps influence the course of events. Points which might now be arised in this context are:

a) Expose the difficulties for developing countries involved in international cooperative projects or institutions. The criteria used to decide the financial quota could be reviewed in light of the different countries. This problem should be studied in depth with the object where appropriate of persuading the international governing bodies to adopt systems of participation which would redress the disadvantages under which developing countries work.

b) By working through the international agencies an effort should be made to create climate in which developing countries can become full members of the big Projects.(E.G. CERN, Fusion Project, Synchrotron radiation project.)

c) Publicise critical analysis of policies, particularly those concern with external cooperation and external agreements, so that the schemes can be seen to be used correctly and in the full.

v) The possibilities of new regional and international research centres should be investigated. Such centres should be evolved on the basis of research groups in the developing countries and/or have a specific objective to aid those countries and possibly adjoining countries. In some instances they may develop from a series of summer schools. As far as po sible they should have a balanced programme between theoretical and experimental physics.

vi) Specifically the proposal to create the Experimental Research Centre at Trieste to be parallel with ICTP should be supported. The reasons for this are because it is deliberately proposed to provide training for physicists from developing countries and in particular to give them trainin in experimental techniques.

vii) The international and national scientific institutions (such as CERN, ESO, Max-Planck Gesellschaft and various Universities) should be requested to develop appropriate schemes of associates and federated institutes, in a similar way as the International Centre for Theoretical Physics has developed and successfully operated for the developing countries. An objective here is to give physicists better access to facilities they have no hope of possessing in their own countries.

9. There are problems in the developing countries concerned with the distribution of physicists between industry, government agencies and universities. Too often physicists appear to be very thinly spread particularly in industry. There is not enough information to quantify this problem but it is recommended that studies should be made to attempt this as part of our final recommendation below.

The fact finding studies should be supported and encouraged to acquire data country by country, suitable for international comparisons, to learn the actual size of problems, and to assess the real position of the developing countries among all developed countries and to follow their development in time and in quality. These studies should involve - input indicators (enrollment, manpower, support) - output indicators (publications, patent and citation rates) related indicators (output vs input, visibility, age distribution, size of basic vs applied research, share of physics in industry, size of physics subfields) and sociological indicators - (demographic migration, field switching, interdisciplinary relationships, demographic distribution of institutions and personnel).

While sufficient scientometric tools exist tools exist to investigate most of these items, it is recognized that at present the most useful are the output indicators.

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SPRING COLLEGE ON AMORPHOUS SOLIDS AND THE LIQUID STATE

14 April - 18 June 1982

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