Science and the Human Condition in India and Pakistan

SCIENCE AND THE HUMAN CONDITION

IN INDIA AND PAKISTAN

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EDITED BY WARD MOREHOUSE

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Frontispiece, courtesy Ford Foundation (Homer Page)

Foreword

DETLEV BRONK

THERE ARE MANY parallels in the growth of science and technology in the United States and in the developing countries of Asia and other regions of the world. The United States, indeed, is itself a developing country – now and throughout its brief national history. It is not necessary to go back very far to the time when – certainly, at least, in the field of science – we were just emerging from a very simple level of development.

It is also significant that in the United States we developed technology before we developed science, because in the pioneering days of our ancestors there was deep need for the useful contributions which the applications of science could make. In the early years of American history, our greatest scientists were men like Thomas Jefferson and Benjamin Franklin – not academic scientists and scholars, but leaders in public affairs who were deeply interested in science because of what its application could give to the people of this young country.

Benjamin Franklin was especially aware that the United States owed much to the other nations of the world in which science was more developed. Franklin was both a first-rank statesman and an eminent scientist; he was a Fellow of the Royal Society of London, a Foreign Member of the Academy of Sciences of Paris, the Academy of Sciences, Letters, and Arts of Padua, the Imperial Academy of Sciences of St. Petersburg – forerunner of the modern Academy of Moscow – and an active, corresponding, or honorary member of scientific societies in many other countries. He was thus able to go on his diplomatic missions as a respected citizen of the world of science as well as of the American colonies or of the new United States he had helped to create. Because of this, he was received both as one who had contributed to the welfare of all peoples and as a patriot seeking to improve the material and political circumstances of his own countrymen. Of special interest is that he carried to his diplomatic tasks a distinctive internationalism that had been developed through his scientific career.

Franklin's scientific background gave him tolerance and breadth of outlook that favored the cause for which he pleaded and gave it reasonableness. That quality prompted him to send the following communication in

1779 to all captains and commanders of armed ships acting by commission of the Congress of the United States, which was then at war with Great Britain.

> Gentlemen, a ship having been fitted out from England before commencement of this war to make discoveries in unknown seas under conduct of that most celebrated navigator and discoverer Captain Cook, an undertaking truly remarkable in itself inasmuch as the increase of geographical knowledge facilitates the communication between distant nations, furthers the exchange of useful products and manufactures, extends the arts, and thereby the common enjoyments of human life are multiplied and augmented and science of other kinds is increased for the benefit of mankind in general, you are recommended, in case said ship should fall into your hands, not to consider her as an enemy nor suffer any plunder to be made of the effects contained in her or obstruct her immediate return to England.

Had we more ambassadors who possess such a sincere and practical basis for internationalism, the affairs between nations would hopefully run a more wholesome course. Were there more scientists and scholars who possess Franklin's sense of social responsibility, such ambassadors might be more numerous.

Franklin's concern for the affairs of science beyond the bounds of this nation has characterized scientists of all ages. One of the first officers to be elected when the Royal Society of London was founded in 1660 was a foreign secretary to communicate between English scientists and those of all other nations. From that time until now, national boundaries and national customs have been recognized as having little significance in the study of most natural phenomena. The properties of inorganic matter and the behavior of living organisms under controlled conditions are not affected by the limits of states. Natural phenomena observed anywhere must be fitted into a consistent pattern of universal validity. That fundamental scientific fact is the basis of the world-wide unity of science, which is reflected in this volume.

To be an isolationist in science is to handicap one's own accomplishment, for the course of new discoveries starts from the territory of established knowledge, and the genesis of new ideas depends upon the work and discoveries of others. Scientists were among the first to realize the practical dependence of their work upon the efforts of those in distant lands; together with the traders of rare goods, we and our predecessors have sought new ideas and new discoveries wherever they are to be found.

Out of this desire for the advantages that can be gained from the work of others has come the frequent reference of a scientist to his foreign colleagues – a phrase so often heard in scientific circles, with all the wholesome implication of the word "colleague" as a partner in intellectual endeavors.

This desire for international cooperation derives from no unique nobility of spirit; it comes rather from the simple realization of the personal advantages that can be derived from the free exchange of ideas. If scientists are better prepared to accept the principle of world unity, it is because they have longer realized the benefits which come from such cooperation.

There is one further and highly important circumstance that influences the interests and attitudes of the scientist. When he considers the social usefulness of his accomplishments, he realizes that he is truly a citizen of the world. The laws of electromagnetic induction discovered by Faraday, the Englishman, have eased the labors of the citizens of many countries. The observations of Galileo and Copernicus and Newton have increased the intellectual horizons of all nations. A scientist knows full well that the furtherance of scientific research in any country increases the intellectual and material resources of all mankind. To further scientific investigation is a common responsibility and yields benefits to all in the community of nations.

Moved by these long-standing convictions, scientists have developed means for mutual assistance in the world-wide dissemination of their thoughts and discoveries. A reminder of this came some years ago when I was negotiating the first exchange treaty between the scientists of the United States and the Soviet Union through our National Academy of Sciences and the Academy of Sciences of the U.S.S.R. As our discussions progressed in Moscow, we soon agreed that we should have such a treaty, in order to overcome barriers that have been put in our way by those who did not understand the international unity of science.

In these days, when the applications of science have such a profound effect upon the material welfare of mankind, the conduct of governments, the course of education, and the utilization of natural resources, it becomes important not only to exchange scientific information and ideas, as we have traditionally done, but also to have a better understanding of how scientists from other countries conduct their work and what their difficulties are. So the symposium on scientific developments in India and Pakistan lies in the well-established tradition of international scientific congresses, the work of the International Council of Scientific Unions, and other international bodies, such as UNESCO. It is a further demonstration that because science has such a profound effect upon the government and sociology of every nation, all members of the world-wide community of scholars and citizens should have a better understanding of how science is conducted and how it is utilized in sister nations.

Twenty years ago, when UNESCO was founded, Archibald MacLeish observed that "since wars begin in the minds of men, it is in the minds of men that the defenses of peace must be constructed." At that time and in the same spirit of high hope, I had occasion to write about the great significance of UNESCO's role in translating scientific discoveries into improving the welfare of the citizens of the world.

> Science has made possible for all people the material advantages now enjoyed by few. She holds the promise of benefits now undreamed-of. If UNESCO can make these benefits more widely available, it will be a true ally of the scientists in fulfilling their function, which was defined by Francis Bacon as "enlarging of the bounds of human empire to the effecting of all things possible through a knowledge of the causes and secret motions of things." Through science, nations can peacefully gain those material benefits which they have sought fruitlessly to acquire through war.

One of the characteristics of our age is the great gap between those who have and those who have not. There is a widening gap between those who have knowledge and understanding and those who have not; between nations and classes of society that have material resources and the means of good health and those that have not. It is my hope that through agencies for international collaboration, and conferences such as the one which prompted the contributions to this volume, we can continue to explore the ways of providing by peaceful means that knowledge and those things which people need for a richer and a happier life.

The last major address made by President John F. Kennedy was at the Centennial of the National Academy of Sciences in November, 1963. In that address, he observed that:

> The ocean, the atmosphere, outer space belong not to one nation or to one ideology but to all mankind, and as science carries out its tasks in the years ahead, it must enlist all of its own disciplines, all nations prepared for scientific quest, and all men capable of sympathizing with the scientific impulse. . . . Science has made all of our lives so much easier and happier in the last thirty years.

He was then referring to the people of the United States, but those who knew him well knew that he was also deeply concerned that not all nations and all peoples have had their lives made easier and happier by the advances of science during those thirty years. He continued:

> The earth can be an abundant mother to all of the people of the world that will be born in the coming years if we learn to use her with skill and wisdom, to heal her wounds, replenish her vitality, and utilize her potentialities. And the necessity is now urgent and world-wide, for few nations embarked on the adventure of development have the resources to sustain an ever-growing population and a rising standard of living. The United Nations has designated this the Decade of Development. We all stand committed to make this agreeable hope a reality. This seems to me the greatest challenge to science in our times, to use the world's resources, to expand life and hope for the world's inhabitants.[1]

President Kennedy closed his remarks by noting that fundamental work in science does not always bring early fruition; he was reminded of what the great French Marshal Lyautey once said to his gardner: "Plant a tree tomorrow." The gardener responded: "But it won't bear fruit for one hundred years." "In that case," said the Marshal, "plant it this afternoon."

These thoughts and ideas reflect my feelings about the deep significance of the symposium at which the essays in this volume were initially presented. It helped to serve the high mission of promoting understanding and friendship as the basis of a more peaceful and prosperous world. One of its real and enduring consequences was to establish friendship and intellectual fellowship among the scientists and scholars from India, Pakistan, Europe, and the United States who took part. This legacy makes it a vital part of the international tradition of science.

Introduction

C. P. SNOW, in his celebrated essay on the "Two Cultures," argues that the central problem confronting mankind in the second half of the twentieth century is the widening gap between the rich and the poor nations. He goes on to observe that:

We cannot know as much as we should about the social condition all over the world. But we can know, we do know, two most important things. First we can meet the harsh facts of the flesh, on the level where all of us are, or should be, one. We know that the vast majority, perhaps two-thirds, of our brother humans are living in the immediate presence of illness and premature death; their expectation of life is half of ours, most are undernourished, many are near to starving, many starve. But this suffering is unnecessary and can be lifted. This is the second important thing which we know—or, if we don't know it, there is no excuse or absolution for us. . . . It does not require one additional scientific discovery, though new scientific discoveries must help us. *It depends on the spread of the scientific revolution all over the world.*[1]

If indeed the scientific revolution holds the key to the central problem confronting us today, what are the prospects for it to spread to other parts of the world? What will be the impact on developing societies as scientific endeavor grows within them? In an illuminating analysis of this prospect, Caryl Haskins suggests a number of reasons why it is critical for the "new nations," as he describes them, to embark vigorously on the promotion of their own scientific revolutions. He points out that "as the whole history of the scientific revolution has demonstrated so vividly, technology cannot remain a vital and a growing thing in the modern world without continuing nourishment from the wellsprings of the living science."[2]

But in addition to this and other obvious circumstances—such as the continuing dependence on foreign technology, which will be inevitable until individual scientific traditions have been established—Haskins points out that there are deeper reasons for developing societies to cultivate scientific endeavor.

Without some structure of indigenous, living science the new nations are likely to have great difficulty in developing standards of judgment by which to ap-

[1] Snow, C. P. The Two Cultures: And a Second Look (New York, New American Library, 1963), pp. 72–73.

[2] Haskins, Caryl P. The Scientific Revolution and World Politics (New York, Harper and Row, 1964), p. 35.

prehend the whole scientific "style" of the natural world. The instinct of what is credible and what is not, that fine sense of the scientifically genuine and the scientifically deceptive, require continuing direct experience for their perfection. . . .

But it is upon the qualities of science as a structure of communication, of philosophy, of faith, that the deepest reasons rest. Without a living science, the new countries will be denied the cultural world fraternity that the fabric of scientific understanding implies. They will be largely excluded from that particular array of lofty concepts that is the priceless heritage of the scientifically literate peoples of the globe. . . .

Finally, and yet more deeply, an original science demands, as it also stimulates, those critical and creative habits of mind so essential to the new nations in every field—the unfettered, flexible, empirical view so essential to their growth and indeed to their very survival as independent states, and still all too rare among them.[3]

It is tempting to seek parallels in the historical experience of other societies that have experienced a scientific revolution. How far-reaching the impact of such a revolution can be on the intellectual and social fabric of society is vividly demonstrated by the British experience. Haskins says:

The major steps in the transformation of world view in British society as a whole from an essentially Ptolemaic concept of the universe to a Newtonian one came, in the main, during that feverish period between 1660 and 1700—approximately eighty years before the start of the great period of British industrial growth. And it is hard, at this remove, to fully comprehend how consuming was its effect on society as a whole. Not only did the outlook of an entire nation during no more than forty years suddenly undergo a transformation more profound than any that wars or drastic political changes might have wrought. Even more prodigiously—and in the context of the new nations perhaps even more significantly—the fever and the excitement of the change were truly universal in the society, reaching far out beyond its rare leaders of Newtonian stamp. This astonishing movement opened windows for the intellect onto vistas so universal and compelling that in less than a generation the vision of a whole people was intellectually transformed.

Of such stuff was the scientific revolution made in its original setting.[4]

Whether or not one concurs with Haskins' analysis of that particular period of English history, there can be no question about the ultimate impact of widespread development of science and technology on Western society. It is also incontrovertible that a prodigious gap in material conditions of life exists between the developing societies and such other countries as the United States, those of Western Europe, and, increasingly,

[3] *Ibid.* pp. 36–38.
[4] *Ibid.* pp. 33–34.

the Soviet Union. To the degree that we have reliable statistical evidence, it would further appear that this chasm is growing wider.

Recognition of these circumstances has led the political leaders of India and Pakistan to identify the development of scientific endeavor and its application in meeting social and economic problems as one of the major national objectives – and therefore a major thrust of governmental activity – in the two decades since those countries have become independent. "It is science alone," said Jawaharlal Nehru, the late Prime Minister of India, "that can solve the problem of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people. Who indeed can afford to ignore science today? At every turn we have to seek its aid. The future belongs to science and to those who make friends with science."[5]

In a similar fashion, President Mohammad Ayub Khan of Pakistan has underscored the vital importance of developing that country's scientific capability as a means of solving critical economic and social problems. "We have won our freedom, but we have yet to win the fight against poverty, disease and ignorance," he has observed. "One of the characteristic features of the last hundred years has been the spectacular improvement in the standard of living in some of the countries. This has been the direct result of advances in science and technology, and their application for the development of natural resources. It is through these means that the advanced countries of the world have been able to insure for their people high standards of living and fruits of cultural progress. We have to do likewise."[6]

In spite of the commitment of national leadership and the significant investment of public resources in developing scientific work in both India and Pakistan over the past twenty years, many problems remain.

Stimulated by the analyses of individuals like Caryl Haskins and C. P. Snow, and animated by a desire to explore such problems further as a means of enlarging understanding of contemporary South Asian society, the Center for International Programs and Services of the State Education Department, University of the State of New York, joined with The Rockefeller University in organizing a program on science and society in India and Pakistan. The program was held in New York City in May, 1966. As our plans developed, we found other organizations and institutions sharing our interest. The Carnegie Endowment for International Peace

[5] Nehru Commemoration Number, *Scientific Reporter*, New Delhi, Council of Scientific and Industrial Research, July, 1964.

[6] Khan, Mohammad Ayub. Speech on the Occasion of Centenary Celebrations of Government College, Lahore, November 30, 1964.

through its program on science, technology, and world affairs, the Office of the Foreign Secretary of the National Academy of Sciences, and the Committee on South Asia of the Association for Asian Studies collaborated in the undertaking, and the Carnegie Endowment joined in formal sponsorship and provided financial support, as did the State Education Department's Office of Science and Technology and The Rockefeller University.

The program held at the University was composed of two major elements. One part was an inventory conference on research needs for the study of science and society in South Asia, which was held on May 2–4 and in which a group of some 30 individuals from South Asia, Europe, and the United States took part. A bibliography was prepared by Patrick Wilson[7] for that conference, and the papers and memoranda on research needs are being published as an *Occasional Publication* of the Foreign Area Materials Center, State Education Department, University of the State of New York, under the title *Understanding Science and Technology in India and Pakistan: Problems of Research in the Social Sciences and Humanities.*

The other part of the program was an international symposium on science in India and Pakistan, in which approximately 125 scientists, scholars in other fields, teachers, and public officials from the United States, Western Europe, India, and Pakistan participated on May 5–7, 1966. This volume contains the papers presented at the symposium.

While the geographical coverage of these papers concentrates on India and Pakistan, there is some reference to other South Asian countries or other parts of Asia, presented for comparative or illustrative purposes. However, the attempt has been to present an interpretive series of essays covering some major aspects of the development of science and technology in India and Pakistan, both historically and in contemporary terms.

After a series of analyses of the historical development of scientific endeavor in the subcontinent and the social and intellectual context in which it is presently being carried forward, attention is turned to growth of scientific education and research and the relationship of government and science in India and Pakistan. A variety of problems is explored, and the development of science and technology in each country since Independence is briefly described. Other aspects of the role of science and technology in modern South Asian society are touched upon, including the kinds of criteria that should be applied to economic allocation of resources for scientific endeavor, external factors in developing scientific work, and the complicated process of using the results of scientific research. Finally,

[7] Wilson, Patrick. Science in South Asia, Past and Present: A Preliminary Bibliography, (New York, State Education Department, Univ. of the State of New York [Foreign Area Materials Center Publication No. 3] 1966).

attention is given to several fields of applied scientific interest, including medicine and public health, family planning, agriculture, and the like.

It hardly needs to be emphasized that, in a single volume of these dimensions, it is not possible to deal with all aspects of such a complex subject as the roles of science and technology in the historical and contemporary development of the South Asian subcontinent. It should also be emphasized that while a number of the contributors carry important governmental responsibilities, each expresses here his own views and not necessarily those of the institution or agency with which he is associated.

A few points regarding editorial practice should be noted. In most cases, monetary values have been expressed in dollars as being more immediately meaningful to readers other than those in India and Pakistan, but in order to be as helpful as possible to readers from those countries, figures have in most cases been given in rupees as well. These conversions have been made at the official exchange rates prevailing at the time of the symposium – Rs 4.75/$1.00. This is important, inasmuch as the Indian rupee was devalued in June 1966, soon after the symposium was held. It should also be noted that the period since these papers were delivered in May 1966 has been one of rapid change in India and Pakistan and that, while a number of factual details have been adjusted to reflect more recent developments, the essays in the volume essentially reflect the situation at the time they were delivered or shortly thereafter, when they were first revised for publication. For the sake of editorial convenience, "science" has frequently been used to cover a wide spectrum of activities ranging from fundamental or basic research to the development phase in utilization of research through technology.

Three of the essays, based on papers delivered at the symposium, have appeared elsewhere since that time. The contribution by Abdus Salam has appeared in essentially the same form in *Minerva* and *Science Reporter*.[8] A number of the points covered by Dr. Nayudamma in his paper have also been dealt with by him in another article, prepared independently for publication in *Minerva*.[9] Professor Faruqi's chapter appeared in substan-

[8] Salam, Abdus. "Isolation of the Scientist in Developing Countries," *Minerva*, Vol. 4, 1966, pp. 461–465. "Problems of Advanced Scientific Research in Developing Countries," *Science Reporter*, Vol. 3, 1966, pp. 452–459.

[9] Nayudamma, Y. "Promoting the Industrial Application of Research in a Developing Country," *Minerva*, Vol. 5, 1967, pp. 323–339. Analyses of both the symposium and the inventory conference on research needs for the study of science and society in India and Pakistan have likewise been published elsewhere. *See*, for example, Ward Morehouse, "Confronting a Four-Dimensional Problem: Science, Technology, Society, and Tradition in India and Pakistan," *Technology and Culture*, Vol. 8, 1967, pp. 363–375; and ibid., "Changing Indian Society—The Role of Science and Technology," *Science Reporter* (New Delhi), Vol. 4, 1967, pp. 179–182.

tially the same form in *Zygon*.[10] In addition, excerpts from the papers by M. G. K. Menon, Mahbub ul Haq, Salimuzzaman Siddiqui, and Professor Salam were included in the January 1967 issue of the *Development Digest*.[11]

Science, as Dr. Bronk and Dr. Hornig emphasize in their contributions, is above all else an international enterprise that knows no national boundaries or political inhibitions. This volume and the symposium on which it is based fall squarely in the international tradition of scientific collaboration. Grateful appreciation must first be expressed to the participants—particularly the contributors to this volume—who came from three continents, if not the four corners of the earth, to take part in the symposium. Furthermore, the contributors graciously acceded to the editor's sometimes impatient requests and the liberties which, on occasion, he took with their original manuscripts in an effort to produce some modest measure of stylistic consistency in the published volume.

Acknowledgment must also be made to the other institutions collaborating in the symposium and inventory conference program. Raymond Platig and William Trainer of the Carnegie Endowment for International Peace provided counsel at many points, as did Richard L. Park, Chairman of the Committee on South Asia of the Association for Asian Studies. The Executive Secretary of the symposium, the late Clearhos Logothetis, who was with the Office of the Foreign Secretary of the National Academy of Sciences, played what can only be described as an absolutely critical role in the final organization and actual conduct of the meetings.

The symposium could not have been held in more pleasant or productive physical surroundings. Detlev Bronk, President of the University, his colleagues, and the University staff extended singularly gracious hospitality to the symposium participants.

Most of the work on the manuscript of this volume was done after I left New York, on leave as Director of the Center for International Programs and Services, to spend the following academic year in India, where I served as the Resident Director of the Educational Resources Center in New Delhi. Further work on the manuscript took place during the period I was in residence as a Senior Specialist at the East-West Center in Honolulu during the summer of 1967. Members of the staffs of both Centers have contributed in innumerable ways to the long process of seeing this volume to the point of publication, as has William Bayless of The Rockefeller University Press from that point onward. I want to pay particular tribute to Mr. Bayless and his staff at The Rockefeller University Press,

[10] Faruqi, Isma'il R. al. "Science and Traditional Values in Islamic Society," *Zygon*, Vol. 2, 1967, pp. 231–246.

[11] Menon, M. G. K., Mahbub ul Haq, and Salimuzzaman, Siddiqui. *Development Digest*, Vol. 4, 1967, pp. 62–84.

notably the Editor of the Press, Mrs. Helene Jordan, for the imaginative and competent way in which they have handled publication of the volume.

My colleagues and associates in New York also played a vital role. Edith Ehrman, Manager of the State Education Department, Foreign Area Materials Center, New York City, confronted with much tact and forbearance a host of logistic complications involved in bringing persons from all parts of the world to take part in the symposium and inventory conferences. The Associate Director of the Center for International Programs and Services, Don Peretz, provided intellectual stimulus at a critical point in the early deliberations.

The origins of this volume go back more than two years to a series of discussions that Don Peretz, Frank R. Kille, then Associate Commissioner for Higher and Professional Education in the New York State Education Department, and I held with Dr. Bronk. These discussions proved highly productive of new ideas and insights into the critically important problems to which this volume is addressed, and all who took part in them bear an important relationship to what has happened as a consequence. Detlev Bronk, who not only stimulated our interest in pursuing these possibilities further but placed all of the facilities of The Rockefeller University at the disposal of the symposium, played what is perhaps the most central role of all as the Chairman of the Symposium.

Like any symposium, the one at which these essays were presented raised more questions than it answered. It also reflected the diversity of viewpoints characteristic of such a complex field of human activity. Indeed, from the very beginning, it was our hope that the combined symposium-inventory conference program would have as one of its major purposes the stimulation of further study and research in India, Pakistan, the United States, and elsewhere on the critically important problems confronting the South Asian subcontinent as it seeks to strengthen its scientific capability in the modern world. If this volume contributes in some small measure toward that objective, it will have amply fulfilled the desires and expectations of those involved in its creation.

Honolulu
August, 1967

WARD MOREHOUSE

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THE SOCIAL AND HISTORICAL CONTEXT OF SCIENCE IN SOUTH ASIA

Science for a Transitional Society: The Indian Case

ASOKA MEHTA

INDIA IS BASICALLY a traditional society. Writing of the country at the death of Akbar the Great in 1605 A.D., W. H. Moreland[1] observes that there was virtually no middle class – few lawyers, professional teachers, journalists, or politicians. There were no men of science investigating the peasants' problems, no skilled engineers designing implements to meet their needs, and no financial talent devoted to organizing their markets and supplying them with capital. Coal was not mined, and production of copper and iron was limited by the scarcity of wood. The living standards of most people were extremely low, and the country was subjected to recurring famines. Although there were some improvements by the time the British left, these did not go far enough to change the character of our society. This we have been struggling to change ever since Independence.

The greatest bane of a traditional society is its frustrating denial of the scientific attitude. The modern age can be distinguished from earlier periods of history by a growing tendency to base all human decisions on objective conditions rather than on preconceptions – a tendency that can be described as the scientific attitude. This attitude is made possible by the younger generation's gradually increasing share of science through education. As a result, decisions tend to become more objective, rational, and wise, increasing the prospect of human happiness and understanding.

This attitude is sadly missing in a traditional society. There, decisions are likely to be based on customs rather than on objective examination of facts and possibilities. Positions are inherited rather than achieved. The

[1] Moreland, William Harrison. From Akbar to Aurangzeb: A Study in Indian Economic History (London, Macmillan, 1923).

ASOKA MEHTA *Minister of Petroleum and Chemicals and Social Welfare, and former Minister of Planning, Government of India, New Delhi*

entire social organization is hierarchical. Finally, being geared to a low level of economic productivity, such a society is perpetually in the grip of a sad fatalism.

All these characteristics are antithetical to the scientific attitude. The scientific attitude engenders decision-making based on facts, questions the rationale of all inherited positions in society that are not based on merit and achievement, breathes a spirit of equality into the structural patterns of groups and individuals in society, and lowers the barriers to economic growth.

One sure way of breaking the traditional closed circuit is to inject it with an ample measure of science. And, I should hasten to add, large doses of democratic practice are also required. It is precisely this process that we have attempted to introduce by administrative means into the social corpus of our country during the last two decades. Different people describe the outcome in different ways, depending on their social backgrounds and personal predispositions. It has been described as disappointing, encouraging, dismaying, and devastating. Whatever the description, there is unanimity on one point – the rigors of a traditional existence have been broken in India once and for all. The Indian society is in a state of political, economic, and social transition. Its full transformation is now only a matter of time.

Let us consider some of the salient features of this transition before describing its dynamic qualities. The major political features, the details of which are too well known to be recounted here, are these: based on universal adult franchise, our young republic of more than 490 million people is the world's largest democracy; three general elections at intervals of five years have, while imparting a measure of political stability, generated a sociocultural tension that has far-reaching implications for economic and social development; from the point of view of causal analysis, the political factor must therefore be judged the most important in bringing about our transition.

The principal features of our economic transition may be summed up as follows. For decades before Independence, the rate of increase in national income was hardly more than one per cent per annum. Between 1950–51 and 1964–65, India's national income increased by about 69 per cent, or at a compound rate of 3.8 per cent per year. The rate of increase during the first five years of this period was 3.4 per cent; that during the second five years, 4 per cent; and that during the last four years, 4.4 per cent. At the time of Independence, barely 5 per cent of the national income was saved and invested. The proportion of domestic savings and investment to national income is at present 11 and 14 per cent respectively. Between 1950–51 and the present time, installed electric power capacity went up from 2.3 million to more than 10 million kilowatts and the freight-carrying capacity of the railways increased from 93 million tons to more than 200 million tons.

The changing face of agriculture between 1950–51 and 1964–65 is shown in Tables I and II.

During this period, the land under irrigation for major and medium-

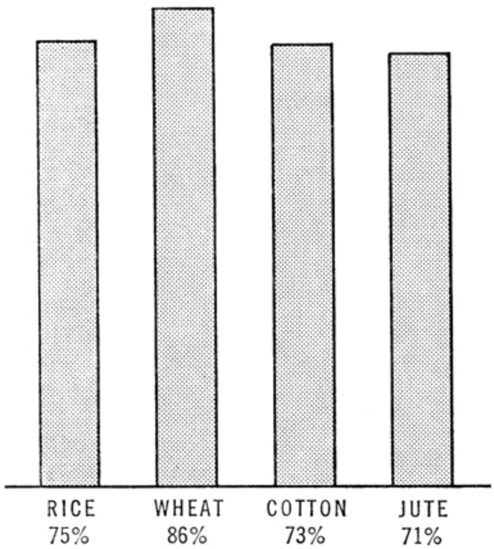


TABLE I

Agricultural production. Percentage increases, 1950–51 to 1964–65.

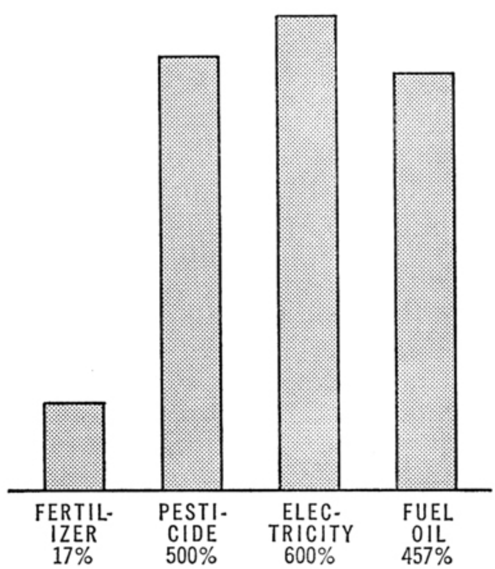


TABLE II

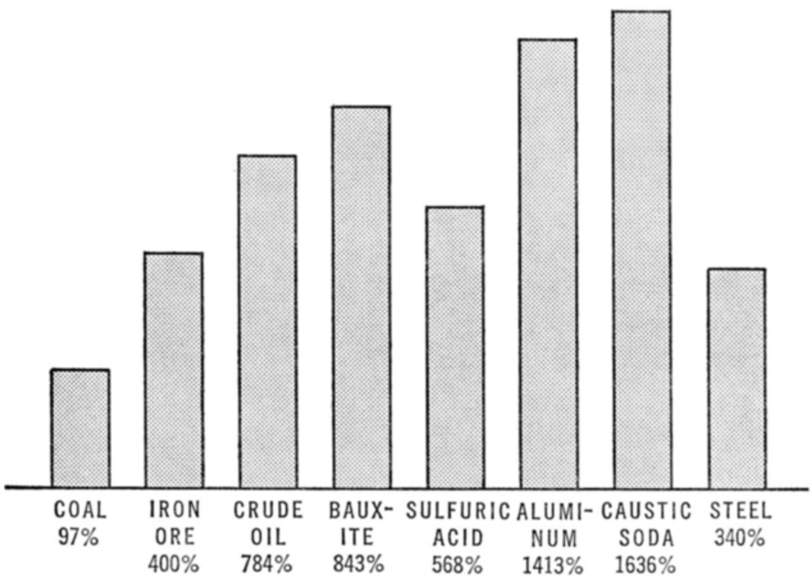
Agricultural consumption. Percentage increases, 1950–51 to 1964–65.

sized projects increased from 23.8 million to 37.5 million acres. We are suffering from a food crisis now, but it is not because there has been no progress in agriculture. It is because the progress is not commensurate with our large population increase and the simultaneous, marked increase in purchasing power.

The industrial index rose from 74 to 175 during those fifteen years. Table III shows a few of the other production gains in specific fields.

TABLE III

Industrial production. Percentage increases, 1950–51 to 1964–65.



Drug production increased in value from 150 million to Rs 1.35 billion and machinery production from 106 million to Rs 2.3 billion.

One of the most dramatic increases was in education. In 1950–51, only 16 per cent of the population was literate. In 1960–61, the figure reached 24 per cent. Today it is more than 30 per cent. Table IV gives some specifics.

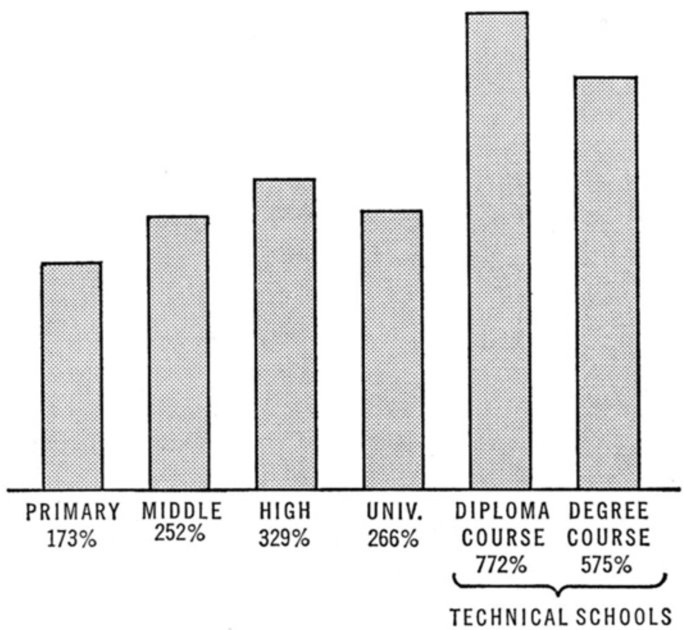
The health statistics are shown in Table V (page 8). Today there are 85 medical colleges in India; there were 30 in 1950–51. Their annual admissions have grown from about 2,500 to 11,500.

It would be wrong to think that the economic and social features of the transition I have just outlined belong in separate compartments. For instance, the process through which an attempt is being made to enlarge technical education is directly complementary to the process of, let us say, industrial development. Reduction in the birth rate, which has great economic implications, is closely related to efforts to enlarge medical and social education. Behind all these interacting social and economic features is the exogenous factor of science as applied to Indian conditions, at present primarily in the form of technology.

To me, science means not only those operations by which we gain a systematic and objective knowledge of the world around and within us,

TABLE IV

School enrollment. Percentage increases, 1950–51 to 1965–66.

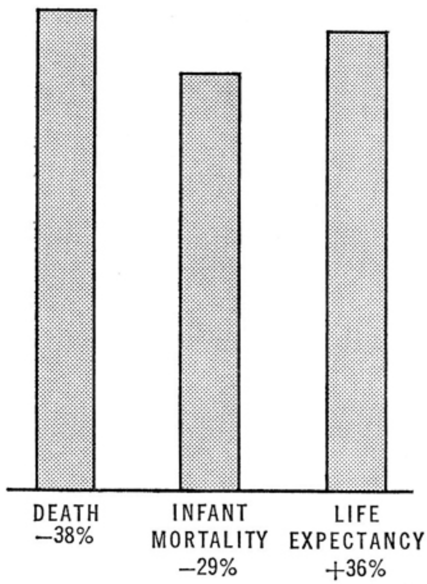


but also those by which we seek to apply our knowledge to control of that world. In this inclusive sense, science is a wide spectrum of activity. At one end is pure research, which seeks to produce new knowledge about nature, life, and society. In the center are applied research and development. The former puts the results of pure research into practical use; the latter adapts the results of applied research for social use. At the far end is technology, the application of all types of research to the maintenance and improvement of a people's material culture.

The large-scale introduction of technology has provided the most important dynamic to the economic and social transition in India during the

TABLE V

Health statistics in percentages, 1950–51 to 1965–66.



last twenty years. Technology has opened up the viaducts of economic growth; it is also playing an increasing role in social transformation. In the last analysis, our planning is an ordered and sequential application of a complex of higher forms of technology to all departments of life. The order and the sequence have been predetermined largely by the endowment of our human and material resources.

In economics, we began by introducing, on a scale hitherto unprecedented in India, different forms of infrastructural technology, more specifically those relating to the development of power, irrigation, and transport. Much of this work was done during the first two Plan periods, when we took up integrated, multipurpose, river-valley projects.

Once the power was secured, we had little difficulty in introducing an industrial capacity based on various technologies. This was started during the Second Plan. Metallurgical development made it possible for us to initiate a heavy-machine industry. We sought to do this during the Third Plan and will continue our efforts during the Fourth Plan (1966–1970). Simultaneously, we are introducing higher forms of chemical technology through petroleum refineries.

Finally, the development of a chemical industry makes it possible for us to introduce far-reaching changes in agriculture through the application of biological and chemical techniques. This is to be our principal task during the Fourth Plan period, which began in April, 1966. We realize that without the introduction of higher technology in agriculture, a total transformation of our still-preponderantly agricultural economy is impossible. But advanced agricultural techniques become really effective only when related industry and infrastructure have been fully implemented. We have thus entered the most critical phase of our economic development.

Along with the ordered introduction of higher forms of technology, we have made an intensive survey of our natural resources. We have investigated ways to use agricultural and industrial by-products and wastes. We have made crop studies and undertaken a soil map of the country. We have made surveys of our forest, ground water, mineral, and energy resources, and of our wastelands. Similarly, we have continued to investigate the requirements for managerial, engineering, agricultural, and other personnel for each phase of introduction of technology, and have carried out a comprehensive manpower-training program.

A parallel advance is the gradual introduction of facilities for pure and applied research and development. During the First Five-Year Plan (1951–1956) we established national laboratories for research in physics, chemistry, metallurgy, fuel, glass and ceramics, food technology, drugs, electrochemistry, road construction, leather, and building. At the beginning of the Second Plan (1956–1961), in addition to research departments in 33 universities and 54 associations of scientific and technological research, we had 16 national laboratories and central research institutes. By the end of the Second Plan period ten more had been added.

All this culminated in March, 1958, with the formulation of our science policy in a six-point resolution. This set forth our determination 1) to cultivate science and scientific research in all its aspects–pure, applied, and educational; 2) to ensure an adequate supply of research scientists; 3) to step up the training of scientific and technical personnel for research, education, agriculture, industry, and defense; 4) to encourage creative scientific activity; 5) to promote the discovery of new knowledge in an atmosphere of academic freedom; 6) to ensure the benefits that application of science brings to the people.

During the Third Plan period, we strengthened research in aeronautics, health, medicinal plants, scientific instruments, petroleum technology, engineering, and mechanical engineering, and started a central design and engineering unit. We also took part in the establishment of an international meteorological center and an international expedition in the Indian Ocean. The Department of Atomic Energy made significant progress in its work during this period.

Excluding research personnel employed in the regular collection of data in such standardized areas as meteorological and hydrological observations, topographical surveys, geographical mapping and surveys, or standard testing activities, those in the social sciences, and the scientific and engineering staffs engaged wholly in production and maintenance and in teaching, a recent estimate showed roughly 12,000 research scientists working, for the most part, on a full-time basis in 1962–63. Of this number, about 3,700 were working in universities. Our research ratio, or the proportion of expenditure on research and development expressed as a percentage of our gross national product, is probably a little less than one-fourth of one per cent. We are conscious that this ratio is much less than that obtaining in more industrialized countries, such as the United States, where the ratio is about 3 per cent, or the United Kingdom and the Soviet Union, where it is close to 2.5 per cent, or Japan, where it is about 1.5 per cent. In China it is probably one-half of one per cent. Because we know that research must figure in our over-all planning, we propose to integrate it more firmly during the Fourth Plan with programs of development in agriculture, industry, education, and other fields.

The preceding paragraphs describe the phased introduction of technology into our economic sphere and its corresponding implications for research planning. Introduction of higher forms of technology and techniques in the social field have engaged our attention simultaneously. In health, our principal—and successful—objective during the first three Plan periods has been to reduce mortality. Now that the mortality rate is coming down, our chief aim in the next three Plan periods is to reduce the birth rate, and already new techniques are under experimentation.

Similarly, the entire field of education is calling for advanced methods of elementary and secondary science teaching, adult education, and so forth. Finally, the most sophisticated applications of the social sciences will be required to bring up the psychosocial level of nearly one-fourth of the population, which comes under the heading of "scheduled castes and tribes." This is perhaps the most difficult area in the whole field of economic and social development, because the techniques we use must be fashioned on the basis of our own experience and culture. Apart from economic research ancillary to the application of social science, knowledge is in a rudimentary state.

All of the economic, social, and political factors described here indicate that the traditional society in India is breaking up and is in rapid transition. This state of affairs has been brought about by the introduction of science, on a hitherto unprecedented scale, chiefly in the form of an ordered and sequential application of a complex of higher technologies in economic and social fields. In economics, the fast development of infrastructural, industrial, and chemical technologies has opened the door to the application of a higher form of agricultural technology. On the social plane, the stage is set for psychology, sociology, and anthropology to bring about a change in the attitudes and motivation of the people, and for the use of new educational methods to revolutionize the learning process.

When the results of these disciplines intersect, the transformation will be complete. Both scientific and social research are catalysts of this process, and will be increasingly important in the years to come.

Nearly a thousand years ago Alberuni wrote in his account of India:

> They have a science similar to alchemy which is quite peculiar to them. They call it Rasayana, a word composed with Rasa, that is, gold. It means an art which is restricted to certain operations, drugs, and compound medicines which are taken from plants. Its principles restore the health of those who are ill beyond hope and give back youth to fading old age, so that people become again what they were in the age near puberty; white hair becomes black again, the keenness of the senses is restored as well as the capacity for juvenile agility, and even for cohabitation, and the life of the people in this world is even extended to a long period.[2]

Nearly two thousand years ago, the Greek poet Dionysius wrote in his *Description of the World:*

> The Indians on the other side of the Indus are variously occupied – some by mining seek for the matrix of gold, digging the soil with well-curved pickaxes; others ply the loom to weave textures of linen; others saw the tusks of elephants and varnish them to the brightness of silver; and others along the course of mountain torrents search for precious stones – the green beryl, or the sparkling diamond, or the pale green translucent jasper, or the yellow stone, or the pure topaz, or the sweet amethyst which with a milder glow imitates the hue of purple.[3]

Our society was once creative and innovational. I am certain we have the good will of the whole world in our struggle to recapture that spirit. A resurgent India is one of the best guarantees of peace through prosperity in South Asia.

[2] Alberuni's India. E. C. Sachau, translator and editor. (Delhi, S. Chand, 1964), pp. 188–189; (*also* London, K. Paul, Trench, Trubner, 1888).

[3] Bose, Atindranath N. Social and Rural Economy of Northern India, ca. 600 B.C.–200 A.D. (Calcutta, Univ. of Calcutta, 1942–1945), p. 245.

Science and Traditional Values in Islamic Society

ISMA'IL R. AL FARUQI

THERE ARE TWO Islams in the world today. The first is the Islam of the Qur'an and the example of the Prophet insofar as it can be critically ascertained. The second is the Islam of the masses of Muslims, their common popular beliefs and customs.

Of the two Islams, the first is scriptural and normative; the second is descriptive and empirical. The first is the divine pattern God has revealed and into the likeness of which the Muslim is to knead and mold creation. It is the ideal ought-to-be. The Qur'an is its repository and final authority.

The second is the human, fallible, and often mistaken pattern by which the Muslim attempts to live up to the divine ideal. This Islam has no single or final authority because, while basing itself on the thinking and deeds of ancestors specially selected from the age of Muslim decline, it must depend on living interpreters of contemporary society.

A people who are conservative and in a state of decay often face national catastrophe. They cling to what they have inherited from their fathers and believe their own survival depends on preserving it intact. In Islamic history, this predilection for survival created for itself an ideological instrument with two edges. On the one side is the positive value of *taqlid*, or tradition; on the other is the negative value of *bid'ah*, or innovation. The first is praiseworthy and guarantees salvation; the second is blameworthy and brings damnation.

Every Muslim is taught that the road to felicity is the path which the *ummah*, or universal community of Islam, has followed in the past and continues to follow, and that outside the *ijma'*, or consensus of the community, is error, peril, misguidance, and certain death. Every Muslim child is exhorted to honor not only the faith of the fathers but their definitions of that faith as well, and to avoid every deviation from tradition.

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The conservatives justify their thesis with abundant quotations from the Qur'an, the Hadith, and other Islamic literature. In support of *taqlid*, conservatives usually press into service such Qur'anic verses as exhort to patience and resolution. Some such verses, popular in conservative apologies, are:

O you who believe, strengthen yourselves with patience and prayer; for God is with the patient. We shall try you with some fear, hunger, poverty, loss of life and wealth; but joy to the patient! Who, in the face of disaster, resolutely say, 'We are God's and to Him we shall return!' (Qur'an 2:153-57)

Those who violate the covenant of God after they have entered therein, denying what God had enjoined and spreading evil—Those are certainly the losers! (Qur'an 2:27)

Be not like her who ravels her knitting after she has made it fit and fast. . . . Let not your foot slip down once it is firmly established and thus expose yourself to the suffering incumbent upon those who turn away from the path of God. . . . (Qur'an 16:92, 94)

Against innovation, the conservatives cite such verses as these:

Some people acknowledge God but understand Him in a peculiar way. Their faith is strong as long as their fortune is good; but once they are put on trial they give up their faith for something else, thereby losing both this world and the next. (Qur'an 22:11)

It is He who revealed to you the Book some verses of which are precise and their meaning unmistakable, and others [of which] are equivocal. Those whose faith is faulty follow the latter with a view to innovate and to interpret as they wish. (Qur'an 3:7)

Other sources are also cited in support of this view. Consider, for example:

Abu Sa'id al Khudriy reported that the Prophet said: 'The time is near when the most fortunate Muslim will be the one who, by following his goats far above the mountainheads, would avoid getting himself involved in innovations in religion.'

Jabir reported that the Prophet said: 'The best words are the words of God and the best guidance is that which Muhammad brought. The worst of all things are the new; every innovation is an error and a misguidance.'[1]

Normative or scriptural Islam certainly demands loyalty to the faith

[1] Al Muntakhab min al Sunnah, editor. The Supreme Council of Islamic Affairs (Cairo, Dar al Kitab al Arabi, 1961), Vol. 1, p. 297, and Vol. 2, p. 169. For an early analysis and refutation of *taqlid* by a Muslim thinker, see Taqiyuddin Ahmad Ibn Taymiyyah (1263–1328) Minhaj al Sunnah al Nabawiyyah (Cairo, Mustafa al Babi al Halabi, 1938); and Shah Waliyyullah (1703–1781), 'Iqd al Jid fi Ahkam al Ijtihad wa al Taqlid (Cairo, Al Azhar Press, 1939).

of the fathers, and it counsels against innovations. However, to say merely this is to oversimplify – in fact, to misunderstand – for Islam stresses loyalty to the faith in contrast to *riddah*, or apostasy, as in this verse from the Qur'an (2:218):

They (your enemies) will continue to fight you until they turn you away from your religion. Whoever of you turns away from his religion and dies an unbeliever will lose his works in this world and suffer eternally in hell.

The contrast, then, is not with deviation from the definitions of the faith without actual separation from the faith or its community. To my knowledge, there is no statement in the Qur'an enjoining loyalty to the faith that is not directed against apostasy or *shirk* (i.e., association of other beings with God). Nor is there any statement enjoining loyalty to the *theolegomena* of the faith, because these came after the Qur'an. Basing itself on the verse "God will not forgive any associating of aught with Him; but He will forgive, to such as He wishes to forgive, the lesser sins" (Qur'an 4:47, 115), Islamic law has prescribed that whoever solemnly testifies that there is no God but God and that Muhammad is the Prophet of God is a Muslim.[2] Islam has known hardly any "heresies," precisely because the religious and legal requirements of Islamicity have always been kept at a minimum. (To use this as a plea for loyalty to the definitions of the theologians is to twist the original meaning of the Qur'anic injunction.)

Paradoxically, there is yet another aspect of this matter, in which *taqlid* is positively condemned by scriptural Islam. The lethargy of the pre-Islamic Meccans to rise to the new faith was a hindrance to the spread of Islam and therefore condemned.

Likewise, we have not sent before you a prophet but that the evil-doers among his people objected 'We found our fathers following a certain course and we shall follow in their footsteps.' He said: 'What? Will you persist even if I bring you a better guidance than your fathers had left for you?' So We punished them. . . . (Qur'an 43:24-26)[3]

To say of anyone that he is a blind follower of tradition, that he does not weigh his spiritual inheritance against new knowledge and newly discovered truth – in short, to impute to him stupidity and folly – is the strongest spiritual rebuke. "They do not reason," "they do not consider," "they do not think," and the like, which can be found on every page of the Qur'an, express this castigation of *taqlid*.

[2] *See* Fyzee, Asaf A. A. Outlines of Muhammadan Law (2nd ed., Oxford, Oxford Univ. Press), pp. 46–51; Muhammad 'Abd al Karim Shahrastani, Al Milal wa al Nihal (Muhammad Fathallah Badran, editor, Cairo, Al Azhar Press, 1947), p. 53.

[3] *See also* 7:27; 21:53; 26:74, where Abraham reprimanded his people for blindly following their ancestors in idol worship and disregarding his monotheistic breakthrough.

If the modernist were to assume the same prerogative of extrapolation as his conservative colleague, he would argue that the Qur'anic condemnation of *taqlid* touches all kinds of conservatism – including Muslim conservatism. The desideratum, from the modernist's point of view, is that any faith, and preeminently Islam, should be held by conviction and not by convention.

The Bedouins of the desert claim that they have *iman* [faith by conviction]. Say [to them] 'You do not yet have that. Rather you have *islam* [acquiescence, or faith by convention]. *Iman* has not yet entered into your minds. . . .' (Qur'an 49:14)

Furthermore, it is held that conviction is always personal and requires constant renewal. Hence the Qur'anic position that *iman* increases by adducing new evidence and new signs. (Qur'an 3:173; 8:2; 9:125; 33:22; 48:4; 74:31)

By far the greatest majority of contemporary Muslims are illiterate and have not yet been confronted with Islamic modernist thought. As a result, they continue to be spiritually dominated by leaders brought up under a *taqlid*-ridden system of education. They adhere to *taqlid*, for *taqlid* is practically all they hear from their religious leaders – mullahs, ulama, Sufi shaikhs, or pirs. Hence, Islamic modernism is to this day the concern of the elite in Muslim societies.[4]

Let us turn now to examine the world view based on *taqlid*, looking first at the realm of knowledge and then at the realms of nature and human action. Islam does claim that the Qur'an is the repository of authoritative knowledge.

That is the Book which no doubt can penetrate and which contains the guidance of the pious. . . . In truth We revealed it, the truth to tell. . . . God has revealed it in the best of form. (Qur'an 2:2; 17:105; 39:23)

These are only exemplary; like statements asserting the divine origin, perfection, authority, and superiority of the Qur'an are ubiquitous in the text. On this point, the Qur'an is far more explicit than the Bible. It claims for itself the status of a book wholly revealed by God, and tradition has interpreted this claim as meaning that every idea, sentence, word, and letter in it is divine. This was the outcome of the Mu'tazilah controversy of the

[4] 'Abbas, Mahmud al and 'Aqqad, Al Islam fi al Qarn al 'Ishrin. Hadiruh wa Mustaqbaluh (Cairo, Dar al Kutub al Hadithah, 1954). The same point is held by most notable Western treatises on modern Islam, e.g., Charles C. Adams, Islam and Modernism in Egypt (London, Oxford Univ. Press, 1933); H. A. R. Gibb, Modern Trends in Islam (Chicago, Univ. of Chicago Press, 1947); Wilfred Cantwell Smith, Modern Islam in India (London, Victor Gollancz, 1946); Wilfred Cantwell Smith, Islam in Modern History, (Princeton, Princeton Univ. Press, 1958); and G. E. von Grunebaum, Modern Islam: The Search for Cultural Identity (Berkeley, Univ. of California Press, 1962).

eighth century concerning the createdness or uncreatedness of the Qur'an.[5] The Qur'an, moreover, called itself Muhammad's only miracle, the only extraordinary proof of his prophethood.

And the unjust, having consulted in secret, asked: 'Muhammad is only a man like you. Would you then accept his magic in full day?' . . . They said: 'What does this man seek, who eats food and goes about in the market place? Had God sent with him an angel to warn, or given him a treasure, or a [terrestrial] paradise from which to eat? Is he not merely a man under spell?' . . . Thus We have revealed to you a spirit from Our realm, previous to which you knew neither book nor faith. We have made it [the book revealed to you] a lighthouse of guidance. . . . Those who do not believe in the Final Day ask you to alter the revelation and to bring them a different Qur'an. Answer: 'It is not up to me to change it; I only repeat what is revealed to me. . . . Had God not willed it, nothing might have been recited to you by me. Have I not been, before this came to be, a fellow of yours for almost a lifetime without any revelation? Do you not reason?' (Qur'an 21:3; 25:7-8; 42:52-53; 10:15-16)

The Qur'an also challenged anyone to write a few verses like its own.

And if you doubt what We have revealed to Our servant, produce a chapter like any of its chapters and call forth your witnesses if you really mean it. (Qur'an 2:23; 10:37-38; 11:13; 28:49-50; 52:33)

Say, even if men and *jinn* were to assist one another to produce a Qur'an such as this, they will not succeed. (Qur'an 17:88)

The enemies of Muhammad, especially some of his compatriots who commanded far greater mastery of the Arabic language than he did, tried and were humiliated. The Hadith has reported a number of such attempts on the part of the greatest contemporary poets of Arabia – Al Walid ibn al Mughirah, 'Utbah ibn Rabi'ah, Unays, and others.[6]

At least as far as the literary and esthetic quality of the Qur'an is concerned, the book is without parallel in the Arabic language. A modern student,[7] following footsteps of the older generation of orientalists, writes:

It is a matter of faith in Islam that since it is of Divine origin it is inimitable, and since to translate is always to betray, Muslims have always deprecated and at times prohibited any attempt to render it in another language. Anyone who has read it in the original is forced to admit that this caution seems justified; no translation, however faithful to the meaning, has ever been fully successful. Arabic, when expertly used, is a remarkably terse, rich, and forceful language,

[5] Shahrastani, K., op. cit., pp. 62, 82, 98, 102, 114, 119. Encyclopedia of Islam (Leiden, E. J. Brill, 1918–1933), *see entries for* "Mu'tazilah," "Qur'an"; T. J. De Boer, History of Philosophy in Islam (E. R. Jones, translator, London, Luzac, 1933); H. A. R. Gibb, Mohammedanism (London, Oxford Univ. Press, 1949).

[6] *See* Al Muntakhab min al Sunnah. Op. cit., Vol. 2, pp. 156–168, or any other Hadith collection; *see also* Qur'an.

[7] Williams, J. A. Islam (New York, G. Braziller, 1961), p. 16.

and the Arabic of the Qur'an is by turns striking, soaring, vivid, terrible, tender, and breathtaking. As Professor Gibb has put it, 'No man in fifteen hundred years has ever played on that deeptoned instrument with such power, such boldness, and such range of emotional effect.' It is meaningless to apply adjectives such as 'beautiful' or 'persuasive' to the Qur'an; its flashing images and inexorable measures go directly to the brain and intoxicate it.

It is equally unassailable on the basis of truth, because it presents no descriptive statement of nature or history which critical investigation can find to be false.

It should be recalled here that the Bible's authority has been questioned in the modern period because archaeology, ancient history, astronomy, and the natural sciences established facts which were at variance with Biblical claims. Objective study of the text exposed errors of simple arithmetic and Near Eastern geography. Finally, literary and textual analysis showed that the Bible is a collection of many books – a true library – written centuries apart, edited and reedited, separated and regrouped, altered and corrected. As a result, the claim that it was the verbatim dictation of God, the writing of Moses, or that the prophetic books were the writings of the prophets themselves, has been utterly squashed.[8]

This can never happen to the Qur'anic text because the Qur'an makes no claim or assertions that can be questioned by the descriptive sciences. On the one hand, its ethical or normative statements are safe *because* they are normative. On the other, its descriptive statements are safe because they belong to metaphysics and transcendental knowledge which science does not question *ex hypothesi*. The origin of space-time and of man beyond space or time, the claim of *creatio ex nihilo*, are not, properly speaking, problems of science.

Critical philosophy has taught us that whereas teleological explanations of phenomena can never be established, they can never be refuted – precisely because of their reference to a realm to which, again by definition, science does not go.[9] Islam also makes a number of allusions to ancient history, such as Noah and the deluge, and Abraham and the idols of Ur. These are not, however, given as history but as religion and morality, i.e., as vehicles for a religious, moral, or exhortative message.

[8] Rowley, H. H. The Growth of the Old Testament (London, Hutchinson Univ. Library 1950); The Old Testament and Modern Study (H. H. Rowley, editor, London, Oxford Univ. Press, 1961); Stanley B. Frost, The Beginning of the Promise (London, Society for the Propagation of Christian Knowledge, 1960); Geddes MacGregor, The Bible in the Making (London, John Murray, 1961); Ernst Wurthwein, The Text of the Old Testament (P. R. Ackroyd, translator, Oxford, Blackwell, 1957).

[9] Kant, Immanuel. Critique of Pure Reason (F. Max Muller, translator, 2nd ed., New York, Macmillan, 1949), p. 516 ff; Immanuel Kant, Critique of Judgment (James C. Meredith, translator, Oxford, Clarendon Press, 1911), p. 61 ff.

The questions of revelation vs. reason, of scriptural authority vs. science, do not arise in Islam in the same sense that they do in the Bible. The conflict is not between science and the Qur'an, but between science and the Qur'an's interpreters, who have made all kinds of irrational and unscientific commentary on it. Despite all the honor in which the works are held, they are doomed to have no value other than to the historian as mirrors of the thinking of their day. Unfortunately, such works in Islam are not holy, and their refutation by liberal and scientific thought has been in progress for over a century and a half. There is hardly a college graduate throughout the Muslim world who does not wish for this critical work to continue and for the hold of these authorities on Muslim minds to break away and disappear. Indeed, each Muslim is enjoined to search his scripture and understand it for himself, as Islam has no church hierarchy and no *magisterium* to pronounce *ex cathedra* on the meaning of scripture. On this score, Islam is more Lutheran than Luther, because its *sola scriptura* is enjoined absolutely without reservations. It is emphatic in its repudiation of the good that is not the result of conscious and deliberate will and in declaring irrationalism and disbelief as synonymous (Qur'an 2:171).

Commenting on the Qur'an verse 2:111 ("Bring forth your evidence if you are truthful in your claims."), a modernist[10] writes:

> The Qur'an taught the Muslims always to ask for the evidence, to build their convictions on evidence. It is natural that the author of a conviction should ask his opponent to produce his evidence; and that was the practice of our noble predecessors. They upheld the evidence, demanded it for everything and forbade the acceptance of any claim without it. It was the ignoble later generations that demanded and applied *taqlid* and forbade the seeking of evidence against what they taught, until Islam almost became its very opposite. . . . Instead of evidence and proof, they demanded conformance with this and that authority, not that these authorities are God or His Prophet, but mere Toms, Dicks and Harrys.

Revelation in Islam is above any reasoning but not above reason. Neither is reason above revelation.[11] Revelation is not necessary, but an act of mercy, a gift from heaven for correcting man's individual reasoning (Qur'an 21:107). But natural reason is perfectly capable of arriving unaided at the truths of revelation. One story in this connection has been known for centuries. It was rewritten by Ibn Sina, and rewritten again by Ibn Tufayl. It is about a lonely child growing up in the woods and nursed by a gazelle. As the child grows, his mind asks questions and finds answers on the basis of evidence furnished first by his senses, then by inductive understanding, followed by deductive logic and metaphysics. When circumstances finally bring the nature-man back to civilization and he discovers the truths of

[10] Muhammad 'Abduh. *Al Manar* (Cairo), Vol. 6, p. 902.

[11] Arberry, A. J. Revelation and Reason in Islam (London, George Allen and Unwin, 1957), p. 34 ff.

revelation, he finds them perfectly in accord with the truths of nature. Thus, by natural reason alone, the truths of revelation are reached because they are one with the truths of nature.[12]

Underlying this position is the assumption of the unity of truth.[13] The reality of the cosmos, Islam holds, cannot be any different from what the Creator who made it has reported about it. On this point, most philosophers and theologians agree, basing their argument on the Qur'anic principle that the works of nature are "signs" and "pieces of evidence" of God. To study the cosmos is to study revelation, and no conflict or difference between them can, by definition, be final. A second, third, and *n*th critical look must expose the underlying unity.

To sum up, we may say that in the realm of knowledge, *taqlid*, which consists of acquiescence to authorities other than revelation and reason, runs counter to normative Islam. The Muslim modernists realize this, and the task of repudiating these authorities and recapturing the freedom to research and to examine is gaining momentum with the spread of education. For such freedom, like the spread of education, victory is certain.

For the Muslim man of the street, the world is composed of natural elements, which obey certain laws, and of supernatural dependencies, which often strike into the world of nature and bring about changes designed to satisfy unknown ends.

Besides God, at whose command everything in nature moves, there are angels and *jinn* who can act efficiently in nature for a good or a bad cause. The common Muslim, moreover, believes in the so-called *awliya*, or saints, whom God had for good reason endowed with the supernatural power to overrule at will the workings of nature and perform *karamat*, or "little miracles." Finally, the common Muslim believes that there are instruments and mechanisms (such as the talismans – Arabic: *tilasm*), by means of which any proper administrator can effect breaches in the laws of nature to suit his purposes.[14]

The common Muslim gets his notions of angels and *jinn* from the Qur'an

[12] *See* Sarton, George. Introduction to the History of Science (Baltimore, Williams and Wilkins, [Carnegie Institution of Washington Publication No. 376]), Vol. 2, Part 1, p. 354 ff; G. Quadri, La Philosophie arabe dans l'Europe medíevale (Paris, Payot, 1960), pp. 71 ff, 95 ff; or any other history of Islamic philosophy, e.g., Ibn Tufayl.

[13] Zurayq, Costi K. "The Essence of Islamic Civilization," *Middle East Journal*, Vol. 3, No. 2 (1949), pp. 125–139.

[14] For a historical account of the superstitious life of Islamic society in Egypt by a native, contemporary historian, see Al Jabarti, 'Aja' ib al Athar fi al Tarajim wa al Akhbar (3 vols., Cairo, Bulaq, 1910); and, by a Western orientalist, Edward W. Lane, The Manners and Customs of Modern Egyptians (London, Everyman's Library, n.d.); by leaders of Muslim modernism, *Al Manan*, Cairo, 1927–1934. For a similar account regarding the Indian subcontinent, see Shah Waliyyullah, op. cit.; and Murray T. Titus, Islam in India and Pakistan (Calcutta, Y.M.C.A. Publishing House, 1959), pp. 137 ff, 153 ff.

(6:112; 43:36; 58:19; 19:83; etc). But he chooses to forget two Qur'anic principles. First, the Qur'an limits the activities of angels and *jinn* to such as God alone permits, thus linking them inextricably to the divine dependency itself.

> We [the angels] do not come down to earth except when commanded by your Lord. For to Him belongs all that is before us and all that is behind us and all that is between. (Qur'an 19:64)

The revelation of this verse was, according to the Hadith, occasioned by the Prophet's asking the Angel Gabriel to make his visits more frequent.[15]

The second principle is that such divine initiative is claimed as a general principle of nature, never as interference in any particular working thereof. The Qur'an is replete with statements of which the following is typical:

> The creation of heaven and earth, the succession of night and day, the vessels which cross the seas for the use of men, the fall of the rain which brings life to a dead earth, the animation of the creatures, the orientation of the winds and subjection of the clouds between heaven and earth—All these are signs for those who reason. (Qur'an 2:164)

Such statements and all those that include assertions about one or more *ayah*, or "given sign," contain a view of nature as an open book which man can read and research in, and which, when properly read, cannot but teach man the knowledge of God. The path of science, i.e., of discovering the laws of nature or creation, is a valid alternative to that of revelation – the truth which is the object of both is one and the same. This "enlightenment" view is not only held by the Muslim modernist. He asserts it in the face of later developments in the theory of knowledge in the West. Indeed, he regards the failure of enlightenment in the West as a failure of rationalist nerve vis-à-vis persistent attacks on two fronts – skeptic British empiricism and dogmatic Christian theology. The enlightenment view is essentially that of Islam. It was also Al Ghazali, the father of the medieval Islamic synthesis, who called nature *tasnif* ("composition"), the word used for an author's writings.[16]

The saints and the miracles are derived from a 1,000-year-old legacy of Sufism, or Islamic mysticism, which taught this doctrine as a corollary of the saint's mystical union with almighty divinity. Conservative Muslims continue to hold to this view despite a fair amount of sophistication in other fields. The latest statement on doctrine by the Islamic Congress[17]

[15] Al Muntakhab min al Sunnah. Op. cit., Vol. 2, pp. 254–55.

[16] Al Ghazali. Ihya' 'Ulum al Din (Cairo, Al Maktabah al Tijariyyah al Kubra, n.d.), Vol. 4, pp. 435–447; G. H. Bousquet, Ghazali, Vivification des Sciences de la Foi, Analyse et Index (Paris, Librairie d'Amérique et d'Orient, Adrien-Maisonneuve, 1955), pp. 429–431.

[17] Sabiq, Sayyid. Al 'Aqa'id al Islamiyyah (Cairo, 1964), pp. 134, 144, 215.

admits the possibility of occasional "breaches" of natural law on the part of the saints, as well as the authorship of the devils (or the non-Muslim *jinn*) for a great many evils in the world. The Sufis overlook the essential disparity of God and man taught by the Qur'an (2:116; 3:18; 5:72; 6:100; 10:66: 21:22; 42:11), as well as the Qur'an's denial of miracles in general and of any miracles of Muhammad except his connection with the Qur'an, the authorship of which is not attributed to him.

Those who disbelieve say: 'If only he brought about some miracle.' But you [Muhammad] are only a warner.... (Qur'an 13:7)

Say: Miracles belong only to God... No prophet may bring forth a sign except with God's permission. (Qur'an 10:20; 13:38)

Add to this the Qur'an's caustic remark to the Prophet almost despairing of converting his fellowman:

And if they persist in turning away from you, would you wish you could penetrate through the earth or ascend to heaven on a ladder, that they may believe?... Do not be like the ignorant. (Qur'an 6:35; see also 6:50; 7:187)

Finally, the instruments of magic are inherited from the traditions of esoterica and alchemy, which in the Middle Ages fused with the ancient religions of the Near East to constitute the mystical, gnostic, popular religion of the masses.[18]

For the Muslim, therefore, the world of nature is a mixture of the workings of nature and supernature. Processes of research and knowing are interrupted by the intrusion of supernatural causation. The Muslim finds this satisfactory, as he is thus obviating further research. As long as he does so, scientific research is impossible.

Turning finally to the realm of human action, we find that, in the view of *taqlid*, the supernatural powers which interfere in nature – and interfere equally in human life – are by definition beyond impediment or frustration. What they decree will necessarily happen and, in fact, all that happens does so because it is predetermined by them. The only attitude consonant with this is passive acquiescence and surrender to the flow of events. Graver still, such flow is neither knowable nor predictable, for its necessity is merely the invincibility of an arbitrary agency. *Kismet*, or the silent acquiescence to the *fait accompli*, is only the ethical side of the gnoseological principle we encountered earlier.

This notwithstanding, the common Muslim has found a way to influence

[18] Lane, E. W., op. cit.; E. W. Lane, Arabian Society in the Middle Ages (London, 1883); Al Jabarti, op. cit., and Alfred Guillaume, Prophecy and Divination: A Study of Man's Intercourse with the Unseen World (London, Hodder and Stoughton, 1938) contain numerous instances and anecdotes culled from Muslim history.

and even to determine supernatural power when it concerns his person. Forgetting that Islam attributes transcendental knowledge to God exclusively (Qur'an 6:59; 7:31; 10:20; 11:123; 16:77; 27:65; 34:3; 52:41; 53:35), the Muslim implores, listens to, believes without question; and in the process is milked of his land, his wheat, his little wealth, his wife's jewelry – indeed even of his freedom and future earnings – by the charlatan magician, esoteric Sufi shaikh or pir, who has arrogated to himself the job of spiritual mentor.[19]

The attitude requisite for technology is absent in popular Islam. Instead of the will to translate scientific knowledge into technology and production of goods and services, there is a blind rush to the shortcuts of magical manipulation.

In popular Islam, therefore, nothing is remembered of the Islamic ethos, of man voluntarily assuming the *amanah* or divine trust first offered by God to heaven and angels and from which they shied away with panic and terror (Qur'an 33:72); of his surpassing the angels by his involvement in this *amanah* to transform the world within and without into the likeness of the divine *sunnah*, or pattern, revealed for this purpose; of his inevitable responsibility as a Muslim for Islamic history, which began as a will to a space-time kneaded and cut after the divine pattern. Through the centuries nothing has become a truer opposite of Islamic ethos than the practical ethic of the common Muslim.

In light of the world view of *taqlid* just explored, let us now consider modern attitudes toward science. For many centuries, the foregoing description has been true of popular Islam. On this account, the Muslim world has known virtually no scientific progress since the close of the twelfth century.

When modern science first came to the Muslim world with the Sorbonne professors and experts of the Académie Française who accompanied Napoleon to Egypt, the Muslims reacted in a manner consonant with this world view, calling science the work of the devil.[20] As they lost ground to the enemy and the West encroached more and more upon their land and resources, they began to realize that science is the greater power and that its nature and methods oppose their traditional view of the world. After telling how pleasantly surprised were the Muslim divines who visited the French factories, laboratories, and libraries, and saw for themselves the accomplishments of French science, al Jabarti, the greatest historian of the period, quotes Shaykh Hasan al 'Attar, Rector of Al Azhar, as saying: "Our

[19] Crooke, W. An Introduction to the Popular Religion and Folklore of Northern India (Allahabad, 1894); L. Bevan Jones, The People of the Mosque (Calcutta, Y.M.C.A Press, 1932).

[20] Al Jabarti. Op. cit., Vol. 3, pp. 35–37.

country must needs change; and many unknown disciplines must be renovated." Al Attar himself wrote:

Many of the books of the French have been translated in our time, in which we read many of their works and came to know of their accomplishments in engineering and natural science. These books tell of the military industries and the instruments of fire. They elaborate their principles and laws and systematize them into an independent science with many branches. Whoever is anxious enough to read these strange compositions will learn many precise and scientific truths.[21]

From this tragic confrontation, two attitudes to science emerged, one antagonistic to science and continuing the tradition of *taqlid,* the other friendly to science and seeking a new relationship between science and Islam. The first view – based on the belief that science is all the work of the devil, whose success must be ephemeral – condemned science and patiently resisted its victories. Some enthusiasts even attempted to refute modern science and deny its accomplishments. Others, in greater despair, identified the works of science as heralds of the end of the world. Naturally, the critical empiricism of science was detrimental to their world view, but theirs was a doomed cause.

The triumph of Western power was equally the triumph of science, and the more this science-based power conquered, the more the *taqlid* viewpoint lost ground. Even the master guardians of *taqlid,* the al Azhar hierarchy in Cairo, had but to lay their eyes on the libraries, laboratories, chemical and military factories, and workshops which the Napoleonic expedition had brought to Egypt, to desire science in good Islamic conscience – indeed, wishfully to predict that "its very successes will soon be the Muslims' own, changing the very face of Egypt."[22] Detrimental to science as its attitude may be, *taqlid* has absolutely no chance of survival as scientific knowledge spreads through education, whether in school or through the cinema and the transistor radio.[23]

The second attitude approved of science and blessed its pursuits. Its adherents, however, did not all maintain the same relation to Islam. Within Islamic society there was a secular stratum – Muslim and non-Muslim – whose case was intellectually the easiest and most barren, and which endorsed the vigorous pursuit of science as a matter of liberation, not only from the superstitions of popular Islam but from Islam altogether. This view had few adherents, mostly non-Muslims, but its advocates were

[21] 'Ali Mubarak. Al Khitat al Tawfiqiyyah fi Tarjumat al Shaykh Hasan al 'Attar (Cairo, Bulaq, 1924), Vol. 4, p. 38.

[22] Ibid.

[23] Corroborating this view is the account of the history of education at Al Azhar University of the Azharite Muhammad 'Abdullah 'Inan, Tarikh al Jami' al Azhar (2nd ed., Cairo, Mu' assasat al Khanji, 1958), p. 151 ff.

eloquent.[24] Most of them were driven to this position by an inherited enmity to the political dominion of Islam. Nonetheless, their view had many practitioners who pursued science and modernized with furious resolution and boldness while keeping their mouths shut regarding religion. The greatest of them on the practical level were Muhammad Ali and his descendants, the Khedives of Egypt, and Jurji Zaydan and the Dar al Hilal school of Egyptian writers.

The periodical *Al Hilal*, the main organ of the school, made its debut in 1892 and has been appearing regularly since. Its greatest challenges to the conservatives were articles written during the nineteen thirties and forties by the strongest adherent of the school, Salamah Musa. Replies and refutations to these articles from the opposite camp appeared in *Majallat al Azhar* during the editorships of Muhammad al Khidr Husayn and Muhammad Farid Wajdi, from 1930 to 1952.

While the secularist may rest assured that science will triumph in Islamic society, it is equally certain that he will never see the fulfillment of his wish for the dissipation of Islam. The capacity to adapt to new challenges, and to absorb and digest them, is innate to Islam.[25] Furthermore, Islamic modernism has identified itself, not without reason, with the progressive forces that count on science and research to secure a brighter future. In fact, in modern Islamic terminology, progress, science, well-being, power, liberty, and dignity have become equivalent to and interchangeable with piety, the will of God, and the will to a space-time in which "God's word is the higher" (Qur'an 9:41). It is unlikely, therefore, that the future in Muslim society will be anything but Islamic.

It is misleading, however, to assume that this favorable attitude to science on the part of Islamic modernism is uniform. Within this camp, two diverse schools are clearly discernible. Both agree on the desirability – nay, the necessity – of both science and Islam. For lack of a better name, let us call the first the One-Book school and the second the Two-Book school.

The One-Book school asserts that Islam, and hence the Qur'an, is the fountainhead of all knowledge, human or divine, scientific or religious, of this world or of the next. The scientific knowledge of the world as well as the achievements of technology are all there in the Qur'an, if not directly expressed, then indirectly through its figures of speech and other allusions.

[24] For a sampling of their thinking on the place of Islam in society, see my discussion of secularism *in* On Arabism: 'Urubah and Religion, A Study of the Fundamental Ideas of Arabism and of Islam as Its Highest Moment of Consciousness, Vol. 1 (Amsterdam, Djambatan, 1962), p. 212 ff.

[25] On this point, *see* H. A. R. Gibb, Modern Trends in Islam, op. cit., Chap. 2; G. E. von Grunebaum, op. cit., Chap. 1.

Whether in his laboratory, in the sky, or under the earth, the scientist with all his discoveries is only writing footnotes to the Holy Book.

The relation of such footnotes to the principal text is that of an example to the general scientific principle, in the case of a theoretical discovery, and that of a concretization of an idea, in the case of a technological invention. Thus, by all kinds of exegetical – or, better, eisegetical – acrobatics, the followers of the One-Book theory found in the Qur'an the theories of heliocentricity, circulation of the blood, evolution, aviation, microbes, submarine vessels, and space travel, and they will probably find all the science and technology of the future.

Obviously, this school was overenthusiastic for scientific development and overhasty in its attempt to reconcile it with Islam. Whether in the Arab world or in the Indian subcontinent, this school has helped reinforce the forces of progress and awakening. However, on the intellectual level it produced nothing but apologetics that Islam is fundamentally hospitable to science. Indeed, the suspicion cannot be ruled out that, in this group's estimation, science comes before Islam.

Sir Sayyid Ahmad Khan's classical statement, "therefore, in this age . . . a modern *'ilm al kalam* (philosophical theology) is necessary by which we may either demonstrate the principles of modern science to be erroneous or else show that the principles of Islam are not opposed to them,"[26] betrays this tacit assumption of priority. "The principles of Islam" are thus subjected to the test of "conformity with nature," or science; the finding is that "when rightly understood . . . the Qur'an and Islam . . . do stand this test and are therefore in harmony with science and progress."[27]

Actually, this school has little notion of what Islam is about, aside from the observance of ritual and some customs, and the overt expression of one's Muslimness through self-declaration. It deserves the appellation "Islamism," for it is more concerned with the consciousness of being an adherent of Islam than with realizing the duties and values of Islam – of being Muslim.[28] Its so-called harmony with science and the principles of nature, therefore, cannot but be superficial, for it is not a harmony with the inner principles and values of Islam, but merely with formal adherence to Islam. In actual fact, it is a will to modernity, pure and simple. Had the desideratum of modernity been not science but something else, the One-Book school would probably have sought and found harmony with it. While charitably we may admit that its kind of apologetics may have served a good purpose,

[26] Khan, Sayyid Ahmad. Lectures (Munshi Siraj al Din, editor, Sadhora, India 1892)

[27] Khan, Sayyid Ahmad. Al Tahrir fi Usul al Tafsir (Agra, 1892), pp. 10–11; Fazlur Rahman, "Modern Muslim Thought," *The Muslim World*, Vol. 45, No. 1, 1955, p. 18.

[28] For an analysis of the principal claims of "Islamism," *see my* On Arabism: 'Urubah and Religion, op. cit., pp. 172–197.

it must also be recognized that traditional values in Islamic society would be in sorry plight if the One-Book school were the only movement on which to depend.

The greater weight in Muslim modernism belongs to the Two-Book school. Deriving its inspiration from the core of the Islamic tradition and making good use of the best that tradition has produced, the Two-Book theory holds the unity of God inseparable from the unity of truth, but recognizes two open ways to it: the way of revelation and that of natural science. Revelation, it claims, informs us about reality in a direct and intuitive way. Although at times the pursuit of truth through revelation has followed methods that can hardly be called rational, this theory holds that revelation in Islam has never alienated itself entirely from reason and has never lost touch with the critical stance. Corroborating this claim is the significant fact that no Muslim has ever written a "dogmatic theology."

Despite this precaution regarding the relationship of revelation to dogmatism, the Two-Book school holds that there is yet another way to reality – the way of natural science – which must be rational enough to satisfy the most fastidious critic. The world of nature, it asserts, is an open book for those who have the intellectual sophistication to read. What they read is the same reality about which revelation informed us intuitively. Man's understanding of either will never be complete, but because both pertain to the same reality, they are, in final analysis, subject to the same laws of intelligibility.

The Two-Book school welcomes science as integral to Islam and equivalent to piety. (Perhaps the noblest and most eloquent praise of science ever written by man has come from the pens of Muslims moved by this kind of consideration. Consider *Jami' Bayan al 'Ilm wa Fadluh wa ma Yanbaghi fi Riwayatih wa Hamlih* [The Comprehensive Account of the Enlightenment and Virtue of Science and of the Prerequisites of Telling Its Truths and of Carrying Its Mission] by the greatest Andalusian theologian and exegete, Abu 'Umar Yusuf 'Abd al Barr al Qurtubi.) The Two-Book school does not conceive of the work of the scientists as an amoral, areligious quest of a reality independent of God. It regards the Muslim scientist as seeking above all to understand nature as God's creation. The scientist seeks to use nature's forces in the service of man as a by-product of such understanding, a privilege granted him by the Creator of these forces.

As a Muslim, the scientist can neither be dictated to by nature or be dominated by his inventions. Above nature stands God; and above the machine stands the Muslim's God-granted privilege of usufruct of the forces of nature. This connection with divinity, with God's will or values, spiritualizes his quest and animates it. It even promises him greater achievement in the fields of science and technology than has so far been achieved anywhere, because, in addition to all the promptings which faith in causality furnishes, his soul is moved by motives of an entirely different order. His research must at least satisfy the demands of causality; but this for him is only the beginning. His soul yearns for further values that demand the transformation of creation itself, the theatre and matter of his destiny.

The most illustrious teachers of the Two-Book theory are Muhammad 'Abduh in the Arab world and Muhammad Iqbal in the Indian subcontinent. Their thoughts diverge on many points and nothing could be more different than their backgrounds and education. However, in their attitudes toward nature, the sciences of nature, and the place of scientific knowledge in the Islamic order of things, their minds meet. 'Abduh writes[29]:

The Muslims have neither opposed science, nor were opposed by science except from the day they alienated themselves from their religion and opposed the study of it. In the measure they separated themselves from knowledge of religion they separated themselves from science and denied themselves its fruits, whereas in the past, the more they knew in religion, the more they did in the sciences of nature. Other people found that the more they cling to their religion, the more they alienate themselves from science, and vice versa. That is why they clamour that science is the work of reason, that reason has no jurisdiction in religion, . . . and that religion is the work of the heart, . . . that the two are disparate and never meet. . . . But here [*i.e.*, in Islam] reason and heart do meet . . . Do not think like some naive men do that there is a difference between them . . . both are two eyes of the soul by which it knows . . . they are mutually dependent. The soul cannot enjoy the advantage of the one unless it can enjoy that of the other. True science is corrective of the heart, and the sane heart is the best co-operator of science. Perfect religion is both knowledge and judgment, mind and heart, reason and perception, critical thought and intuition. If one falls down, religion cannot stand on the other. . . .

Says Iqbal[30]:

In Islam, the spiritual and the temporal are not two distinct domains. . . . In Islam it is the same reality which appears as the Church looked at from one point of view and the state from another. . . . Islam is a single unanalysable reality which is one or the other as your point of view varies . . . this ancient mistake arose out of the bifurcation of the unity of man into two distinct and separate realities which somehow have a point of contact, but which are in essence opposed to each other. The truth, however, is that matter is spirit in space-time reference. The unity called man is body when you look at it as acting in regard to what we call the external world; it is mind or soul when you look at it as acting. . . .

The first Islam, of which I spoke in my opening paragraphs, has the

[29] Muhammad 'Abduh. Al Islam wa al Nasraniyyah Ma'a al 'Ilm wa al Madaniyyah (Cairo, no publisher, n.d.), pp. 159–160, 142–43.

[30] Muhammad Iqbal. The Reconstruction of Religious Thought in Islam (Lahore, Shaikh Muhammad Ashraf, 1958), p. 154.

most favorable attitude to science; the second is severely antagonistic to scientific research. The first believes it has everything to gain from the progress of science; the second believes it has everything to lose. The march of science, however, is inevitable, as is its eventual victory over the second Islam. Any friend of science will therefore wish for that day to come, and indeed he will hasten it; but he should remember that in this matter he can have no better ally and friend than the first Islam.[31]

Indeed, since the first Islam is a real force in the Muslim's consciousness, although covered with the ashes of a long decline, it is vain to think that it can be overlooked, bypassed, or successfully combated. The problem of the progress of science in Islamic society is, therefore, not how far that society can liberate itself from the clutches of its religion, but how more truly Islamic can the society make the substance of its educational endeavor.

[31] Shahrastani, K. Op. cit.

Tradition and Modernization in India: Synthesis or Encapsulation?

AINSLIE T. EMBREE

IN THE INTRODUCTORY CHAPTER of the Third Five-Year Plan, an attempt was made to provide philosophical underpinnings for the massive schemes for modernization of the Indian economy by relating them to the cultural values of Indian society. The assumption of the plans, made explicit in these pages, is that while the science and the technology of the modern world will transform the traditional economic and social institutions of India, the cultural values that constitute the distinctive core of Indian civilization will be preserved. The implications of this assumption are so interesting and of such practical concern that I would like to make a tentative exploration of some of them.

The exploration will begin with a general hypothesis about Indian civilization and then will identify a common way of looking at Indian civilization, which, to me, seems to do peculiar disservice to our search for understanding of the dynamics of Indian society. Next, we will look briefly at the characteristic assumptions that underlie that extraordinarily complex civilization. Finally, this discussion will suggest tentatively the relevance of the nature and form of Indian civilization to the relationship between science and society in the subcontinent. Implicit in the discussion, even if it is never explicitly formulated, is the question: "Can science, as understood in the West, find a home in Indian civilization?" This essay will try to touch upon the periphery of an answer.

The general hypothesis about Indian civilization, with which we will begin our exploration, is neither new nor particularly controversial. It is that Indian civilization constitutes a complete universe in itself, and that for reasons too complex to analyze here, there developed in the Indian

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subcontinent a society and a culture that differ in many fundamental ways from other major historical traditions. The origins of this society were certainly visible by 1500 B.C. To a truly remarkable extent, all the main lines of development in thought and cultural patterns were clearly present by about 300 B.C., by which time the ways of thinking, the styles of social action, the configurations of human behavior, all were formed in the physical matrix of the subcontinent. They have endured with astonishing persistence through periods of internal revolution and external invasion to provide the fundamental patterns of thought and behavior for the overwhelming majority of the peoples of India. All three great indigenous religious traditions—Hindu, Buddhist, and Jain—share equally in this pattern.

In short, India is heir to a way of thinking, a way of living, an understanding of the world, that is *sui generis.* Within Indian civilization all human questions have been asked and have been answered, and they have been answered in ways that seem to have been peculiarly satisfying to the human spirit. There appears to be no explanation for the endurance and persistence of Indian social values and patterns of ideas and concepts, except the presupposition that, taken together, they form a way of existence that solves both problems of institutional organization—how men live together and interact as social beings, and problems of psychological experience—how they come to terms with those questions conventionally subsumed under the rubric of religion. This merits emphasis because of its great importance in any attempt to understand the whole process called modernization.

Closely related to this hypothesis or assumption that Indian civilization forms a universe of its own is an interpretation of Indian civilization that has gained great currency in the last hundred years or so. It is the belief that Indian civilization is, in specific contrast to other great world cultures, sympathetic to ideas and values from outside its own system. One can choose the words that are used to describe this understanding of Indian civilization from a hundred books or a legion of speeches. Hindu society, it is said, is eclectic; it is open to new influences; it is absorptive; it is synthetic; it is, to sum it up in a word, tolerant.

For reasons to be suggested subsequently, this is, in my judgment, a radical misunderstanding of the essential characteristics of Indian civilization. It is clearly an interpretation born out of ideological commitments at once noble and politically valuable. Briefly, this understanding of Hindu civilization (the words Hindu and Indian are being used interchangeably to describe the civilizational complex that emerged in India) is the product of two sources that fed and reinforced each other. One is German idealism of the mid-nineteenth century; to a remarkable extent, the India of tolerant spirituality is the product of German philosophy and philology. The other source is Indian nationalism. The requirements of nationalism dictated an interpretation of Indian history that would make possible the fulfillment of the idea of a political unity. One may note in passing that the belief that a unified nation is somehow the final achievement of political wisdom is also, to a considerable extent, a product of nineteenth-century European nationalism.

My own understanding of Hindu civilization is that, of all the great world cultures, it is in fact the least absorptive and the least eclectic, and the truly astonishing factor in Indian civilization is the endurance and persistence of its style and its patterns. What people have in mind when they speak of Indian civilization as absorptive, as eclectic, and as tolerant, is its ability to encapsulate other cultures and to make it possible for many levels of civilization to live side by side. But encapsulation is not toleration nor is it absorption.

The example that comes most readily to mind is religion. Compare the history of Christian theological thinking with that of Hindu thought. Christian theology shows the imprint of every cultural wind that has blown through the centuries. The "death of God" adherents are but the most recent manifestation of a necessity Christian thought has always felt – to incorporate within itself the current values of society and the influences that beat in upon it from the intellectual world. The contrast with Hinduism is startling. Christian theologians argue over whether their foundation documents were written in A.D. 44 or A.D. 54 The dates of the great texts of Hinduism are wholly irrelevant. They express, for believers, truths that are timeless and changeless; internal evidence cannot date a Hindu scriptural text even approximately. Hindu thought at its deepest and most profound level refuses to be concerned with insights and values from outside its own cultural context.

Some explanation of this phenomenon – the ability to encapsulate almost any religious or cultural entity, but at the same time to admit no genuine dialogue, no possibility of interaction at the most profound levels of human discourse – will be attempted as we identify those values and assumptions that underlie Indian civilization. It is these great clusters of ideas, concepts, social practices, and philosophical speculations, all inextricably interwoven by human ingenuity and the loom of history, that make Indian civilization a universe unto itself and one that encapsulates but does not synthesize.

At least five unquestioned assumptions comprise the basic fabric of Indian thought. This is not to commit oneself to the theory that, in any sense, these particular ideas created Indian society, nor does it assign them a priority in chronological sequence to all other ideas. It is quite as plausible to argue that they are relatively late articulations of the inner structure of a society that had already developed in response to other pressures. But they are so characteristic of the society, so pervasive at all levels of culture, so much a part of the verbal and literary tradition, that they can be identified as the keys for an understanding of Indian culture.

The first of these key concepts is an understanding of the nature of time, which stands in radical contrast to that inherited by the West from Hebraic tradition. The Hebraic, or Biblical, concept of time, which in secular versions still dominates our ordinary Western thought, is that of a linear progression, a movement that has a beginning and will have an end. This view of time is intimately bound up with man and his fate. Events within the movement of time are unique; they happen once and for all, and there is no repetition.

The Indian understanding of time has almost nothing in common with this view. First of all, time is not thought of in terms of linear progression, but of cycles, which repeat themselves endlessly. Second, and this is of great significance, these cycles are conceived of in terms quite beyond the ability of the human imagination to encompass. Time moves in cycles within cycles, all of immense duration, giving human history a setting not of thousands of years, but of thousands of millions of years. The duration of the eras is of more importance than their cyclical quality in determining man's relation to them. The greatest estimates that have been made for the age of the earth, not to speak of man's existence, pale into insignificance before the Indian concepts of the duration of the world and man's involvement in it. Three hundred million years is the length of the fundamental cycle, but this is only a rounding out of the full story before it all begins anew.

Another characteristic of Indian time is that it has no beginning or ending; there is only endless repetition of the immense cycles. Time and the universe are involved in the perpetual process of renewal and decay. Bhartrihari, the great Sanskrit poet, pays homage to the power of time in a vivid verse[1]: "Great was the king with his circle of courtiers; the ladies' moon-like faces; the host of haughty princes; the bards and their tales; Homage is due alone to time which swept them all from power to the path of memory." But within the cyclical movement, the proud kings and all the events in which they were involved recur perpetually. Everything has been and everything will be; there is no unique event, nothing that has been that will not be again.

Finally, nothing is more indicative of the Indian view of the all-encompassing nature of time than that the gods, no less than men, are part of the eternal cycle. This is of profound importance for all Indian mythical state-

[1] *Bhartrihari*, verse 169. Barbara S. Miller, translator. (New York, Columbia Univ. Press, 1967.)

ments about reality. The gods, as a famous hymn in the Rig Veda puts it, are this side of creation. There is no dividing line between the human and the divine. This means there is no "holy history" that is not also human history. There is a continuum between man and nature and between man and the gods, because all are bound in the movement of time.

The significance of this concept of time for man's view of his place in the cosmos is obviously great. Quite clearly, there is no place for the unique event, for the moment that happens only once; nor is there much likelihood of man taking too seriously his achievements in constructing political institutions. There is not likely to be, in short, that kind of attention to political history that has been common in the Western world and in China.

Closely related to the idea of time is a second great assumption of Indian thought – the idea of karma, the belief that every action, whether mental or physical, of necessity produces an appropriate result. A good action produces good fruit, an evil action, evil fruit. Karma is a law of nature, as inexorable and yet as just as the law of gravity. It has nothing to do with a deity. Two of the great Indian systems, Jainism and Buddhism, accept the idea of karma without question, but explicitly reject the concept of a deity. Karma works almost mechanically; there is no interference by any kind of supernatural agency.

Inextricably linked with both the idea of karma and of time is that most pervasive of all Indian assumptions about the nature of the universe – belief in rebirth or reincarnation. Because the full working out of karma cannot find fruition in one life, the results determine rebirths. Given the concept of endless cycles of time and of endless repetition, the possibilities for development of the concept of rebirth are very great. Rebirth becomes part of an endless chain of existence, of which karma is the motivating force. The three concepts of time, karma, and rebirth interweave with each other, producing the color and pattern of Indian life, undergirding every aspect of human existence. Few people who live fully within the context of Indian society, even those who are not Hindu, escape the influence of these ideas. They give meaning to human existence and answer the hard questions that life puts to men. Most notably, they answer those questions that have haunted Western man. Why do the evil prosper? Why do the good suffer? Why is there evil?

There are two further assumptions that enrich and deepen Indian society. One is the set of values and attitudes summed up in the word dharma. Dharma can be defined as duty, or as conduct that is expected of a person in society, or as law, or as morality, or as social usage. Perhaps the best definition, however, is that it is the specific obligations that life itself imposes upon each individual. Each man, at every moment of his existence, has a duty that is defined for him by birth, by the most fundamental fact of human existence – of being born within a social group. What is involved here in a formal sense is that most ubiquitous of Indian institutions – the structuring of social relationships known as caste. In social terms, dharma means that, as a human being, everyone has obligations determined by his position in life – in essence, by his birth. No man can perform another's duties or obligations. What is right for one man may be wrong for another. As one of the most famous scriptural texts[2] puts it: "Better to do your own duty badly than another's well."

This discussion of dharma leads to the fifth great assumption of Indian culture – the concept that there are many levels of truth, although all truth is one. The truth for one man may be quite different from the truth for another man. For this reason it is possible, to take a familiar example, for a Hindu to declare that all religions are true, or, in the modern world, that all political ideologies are true. This is always a baffling statement that suggests intellectual confusion. What is meant is that particular religious practices are true for those who believe in them.

Indian thought explicitly rejects the idea that all men can have the same perception of truth, the same understanding of reality. It seems obvious to Indian civilization that all men do not have the same capacity for mental, moral, spiritual, or physical achievement. Here the contrast with Islam and Christianity, two religious ideologies that came into contact with Hinduism, is complete. Both those religions have at the heart of their systems an obligation to assert that all men can share in the same vision of truth. Before this assertion Hinduism is both sceptical and affronted. The claim that a truth exists which is not only perceivable and available to all men, but which they should accept, as it alone is truth, is a denial of all the complex understanding of the universe built upon the five great assumptions – time, karma, rebirth, dharma, and truth itself.

At no point is Indian thought more alien to other modes of thought than in this assertion of many levels of truth, which gives to Indian civilization the characteristic that has been mistakenly understood as toleration. What follows from it is not toleration; rather, all truths, all social practices, can be encapsulated within the society as long as there is willingness to accept the premise on which this encapsulation is based. The result, as was argued in the statement of my general hypothesis at the beginning of this chapter, is that a universe of thought and feeling and social action was created that is complete in itself, neither admitting nor needing any external influences.

How, then, has Indian civilization reacted to alien influences? Many intruders, some with violence and some with pleading, have broken in upon the geographic region of this self-contained civilization. Or, to put

[2] *Bhagavad Gita*, III, 35.

directly the problem that is implicit in this discussion, if we assume the validity of the analysis of Indian civilization made here, is there any conclusion that one may draw as to the incorporation of science into the existing traditional society of India?

Three historical moments of confrontation between Indian society and alien intrusions illustrate very well the problems of the self-contained universe of India meeting external forces. One is the coming of Islam to India – to the periphery in the eighth century and to the political center in the twelfth. For five hundred years Muslim sovereignties controlled much of India, including the great religious and cultural heartland of the Gangetic plain. What was the effect of these centuries of contact between Islamic and Indian civilizations in terms of transference of fundamental values and attitudes from one to the other? One is compelled to answer that there was remarkably little.

To provide such an answer immediately shows one's alignment in a great historiographical argument, for there are historians who assert that, in fact, there was much interaction. They are able to give undoubted examples in painting and architecture. Much more dubious is the attempt to show relationships between Sufism and Bhakti. But only an irenic nationalism, dedicated to the proposition of the fundamental unity of Indian culture, including its Islamic component, can find any real evidence of a lasting movement from one culture to the other. The reason is fairly simple. Both civilizations expressed their deepest values in a vocabulary and form that were recognized by the other as religious – that is, pertaining to those aspects of culture most carefully guarded from change. Given this, creative interchange was unlikely in those areas that both groups felt to be of most ultimate consequence.

Another moment of contact with an alien civilization came at the end of the fifteenth century, when the Portuguese were active in establishing political power and supremacy in the Indian Ocean. It would have been perfectly possible at that time for Indians who were interested in European ideas to have learned from the Portuguese something of the events and movements that were transforming Europe. Yet, as far as we know, no Indian showed any such interest. This lack of curiosity about European life is illustrated in a revealing example. In the sixteenth century the Portuguese introduced the printing press into India. Apparently it did not occur to anyone in India that it would be possible to make use of the invention for Indian purposes. The explanation is surely to be found, as in contacts with the Islamic world, that the articulation of ideas and values – for the Portuguese no less than the Indians – was in a religious vocabulary. The questions the Portuguese asked and answered were precisely those for which satisfactory answers had long existed in the universe of Hindu civilization. The printing press had been introduced by the Portuguese to print catechisms for use in religious instruction. The Indians would understand it as a part of an alien and oppressive religious ideology. Only later would it be seen as an instrument that could be used to serve Indian, even Hindu, ends.

The third moment of contact had very different results from the first two. This came with the establishment, through the East India Company, of a Western political power in Bengal at the end of the eighteenth century. The significance of this event is not that it was the British who became the successors to the Nawabs of Bengal – themselves the successors to the Mughal Empire in eastern India – but rather the timing of the intrusion.

It cannot be emphasized too much that the meaning of British rule in India in the nineteenth century must be seen primarily in terms of the changes that were taking place in the Western world during the period of British hegemony. It is significant that the British came as the inheritors of political and cultural revolutions that had already profoundly modified Western life. The Enlightenment, Locke and Hume, the French Revolution, the Industrial Revolution, the Utilitarians, the Evangelical Movement – all these influenced the new political arrangements that were made in India at the beginning of the nineteenth century. Unlike the Islamic peoples and the Portuguese, the British did not articulate the values and attitudes of their culture in religious terms. Instead, they used a vocabulary that made it possible for Indians to accept new ideas without any apparent infringement on the central core of the religious and cultural tradition they had so long guarded from alien intrusions.

As a result, the early years of the nineteenth century saw a phenomenon unknown before in India – the hungry quest for the science and technology of the Western world. An instructive example illustrating the changed reaction comes to mind. Recall how the writers of Greece and Rome, from Herodotus on, made frequent references to India; yet there is not a reference in the vast body of Indian literature, much of it written during the same period, to the Western world. In the nineteenth century the tide turned; the West became of central concern for at least a group of Indian intellectuals. This is only partly explainable in terms of political dominance; alien political rule was no new experience to India and, as has been suggested, it had not before excited any interest in the world beyond India. Alberuni's famous characterization of Indians was no longer true. He said they were a people who thought there was no other country but theirs, and who, if you told them there was learning elsewhere, would think you both an ignoramus and a liar.[3] Ram Mohan Roy is only the most familiar

[3] Alberuni's India. E. C. Sachau, translator and editor. (London, K. Paul, Trench, Trübner, 1888) p. 23.

name among the many Indians who sought, in the language of the cliché, to wed Western science and technology to Eastern learning.

Yet despite the emphasis of Ram Mohan Roy and others on the utility of Western science for the rejuvenation and enrichment of Indian life, one must record that, after all, the nineteenth century saw relatively little of Western science introduced into India except in the form of applied technology, such as railroads and telegraphs. Indians received most avidly not science but Western literature and political science. The explanation usually given for this is that the alien government would not permit the introduction of science lest India become a commercial and industrial rival to the imperial homeland. There is some truth, but not much, in this analysis; it is an explanation created to serve nationalist needs.

The truth appears to be that while in the British encounter there seemed to be a ready acceptance of the dominant cultural patterns of the West—those associated with Western achievements in science and technology—in fact, the aspects of Western thought that appealed to Indians were those most congenial to the traditional values of the intellectual elite of India. Western literature and political science were easily accepted because, while they presented new avenues for intellectual exploration, they posed no threat to traditional society and were amenable to categorization under forms familiar to the culture.

This brings us back to the question raised in the beginning. Can science, as understood in the West, find a ready and compatible lodging within the context of those values and attitudes that give Indian civilization its distinctive characteristics? I believe that most modern Indians would answer not only with a resounding affirmative but would even deny the question's validity. I have tried to suggest that there are, in fact, reasons to question the facile optimism that forms so much of the discussion of modernization and planning.

The introduction to the Third Five-Year Plan provides, as was suggested in the beginning, an almost archetypal example of the refusal to examine possible conflicts between the values of Indian culture and those of the Western world. The opening paragraphs of the Plan speak of the cultural and moral values that have governed India for thousands of years. But, the writer of the introduction goes on to argue, these values are not bound up in any integral way with the traditional social and economic structure that, in fact, exists in India. The Plan states that it is possible to maintain these values that have characterized Indian culture, and at the same time to create a new society "through the impact of the scientific and technological civilization of the modern world." The magic word "synthesis" is then evoked; India has the peculiar capacity to synthesize the cultural inheritances of her past with the artifacts and ideas of modern science.

The interpretation of Indian society given in this brief essay suggests that this faith in a synthesis – born, in my judgment, of a false interpretation of Indian culture – may be wholly illusory. The scientific and cultural impact of the modern world may indeed transform it. However, the process may be marked not by synthesis, but by erosion and decay of the traditional values and ideals of Indian culture. This conclusion may, of course, be accepted with equanimity or even pleasure, but it is surely worth consideration and thought, for something quite different may happen. As in previous encounters with alien elements, Indian society may encapsulate the scientific and technological learning of the modern world. In practical terms, the result would probably be the creation of urbanized, Westernized, industrialized enclaves in the midst of a countryside still traditional, still living by the codes and values of the Indian inheritance. Indeed, many have already discerned the appearance of such enclaves. Their emergence will surely subject India to peculiar social and political stresses. But whatever the future may be, one can fairly confidently predict that it will not be toward the kind of synthesis of which the Third Five-Year Plan spoke with such wistful optimism.

Historical and Social Factors in the Development of Science in India

A. RAHMAN

SCIENCE AND TECHNOLOGY, as a means of acquiring knowledge and utilizing it for the benefit of man, are cumulative in character. The information gained by various methods and techniques is analyzed and sifted, and the central core is used as a basis for further development. The process requires continuity of effort and, hence, of institutions. Modern science is differentiated from ancient and medieval science by this continuity.

The formation of scientific societies and universities established the continuity of effort in Europe. In addition, their coming into being made possible the exchange of ideas, interaction among different schools of thought, and a more rapid dissemination of information. The last was accelerated by the spread of printing. These developments interacted with others in the social sphere; this helped to broaden the base for science and to influence its organization, structure, and character.[1] For instance, the idea of ultimate use had a profound influence on problems taken up for research. The interaction of science with technology gave science a new edge – what Whitehead calls a direction in time.[2] Its interaction with social values gave rise to new philosophical perspectives on society.

In contrast to the medieval outlook of esthetics, the concepts of utility and economics had a major influence on science and social values. The effect of science and scientific ideas on social development could be judged from the controversies and variant philosophies that emerged as a result of their interaction at different levels and in different fields.

[1] Sarton, George. Introduction to the History of Science, Vols. 1–3 (Baltimore, Williams & Wilkins [Carnegie Institution of Washington Publication No. 376.] 1947).

[2] Whitehead, Alfred North. Science and the Modern World (Cambridge, Cambridge Univ. Press, 1936).

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As a result, a major effort was made to link the then-current developments with scientific efforts that took place in ancient and medieval periods. Humanists, and later scientists, looked back to Greece and took over the rational and scientific part of that tradition, making the tradition appear continuous from ancient times to modern. This traditional knowledge was subjected to critical scientific analysis, and what was relevant and consistent with the newly-acquired knowledge was absorbed and made the base for further development.

In this process, three things were achieved: a precise language, capable of expressing new ideas without ambiguity, was developed; elements that were not consistent with the newly-acquired information were removed from the main body of knowledge; a set of intellectual values emerged that tended to guide and shape fresh endeavors. One significant change in outlook, engendered by these developments, was a growth of confidence in man and his future progress; a belief that, given enough time, man is capable of developing through his efforts instead of degenerating.

Against the pattern of development in Europe, we are faced with two major breaks when we try to understand the scientific tradition in India. These breaks were responsible for the discontinuity of the entire scientific movement and made each phase a separate entity – with consequences of far-reaching effects. To explain modern science in India, it may be pertinent to go into some detail.[3]

In ancient India, the language of science was Sanskrit. Major contributions were in the field of mathematics, medicine, and astronomy. In mathematics, the main branches were arithmetic and algebra. However, the Indian contribution to geometry, if any, was negligible, and this can be related to the lack of concept of space. For this same reason there was no contribution to geography.[4,5,6]

From the point of view of methods and techniques of acquiring scientific knowledge, there was considerable development of observation, but at the same time there was a lack both of experimentation itself and of a positive attitude toward experimentation. Logical analysis as a tool for refinement of ideas and generalizations was also considerably developed at various levels. In individual branches of science, thinking in general, and methods

[3] The Legacy of India, edited by Geoffrey Theodore Garratt (Oxford, Oxford Univ. Press, 1937).

[4] The Cambridge History of India, edited by E. J. Rapson (Cambridge, Cambridge Univ. Press, 1922–1937).

[5] History and Culture of the Indian People, edited by Ramesh Chandra Majumadar (Bombay, Bharatiya Vidya Bhavan, 1952).

[6] Winternitz, Moriz. A History of Indian Literature, Vols. 1 and 2. S. Ketkar and H. Kohn, translators. (Calcutta, Univ. of Calcutta, 1927–1933); Vol. 3. Subhadra Jha, translator. (Delhi, Motilal Banarisidas, 1963.)

and techniques of analysis, resulted in a rich and extensive effort toward working out generalizations. Based on these generalizations, philosophies of thought evolved. The philosophies, however, were closely associated with various religious and social schools of thought in the country.[7]

The principal method of acquiring knowledge and continuing the tradition was centered around an individual – a *guru* or teacher. Each gathered pupils around him, and the group dispersed after his death. The early universities of Taxila and Nalanda were first steps toward formalized teaching, but their character and the reasons for their disappearance must be fully studied before anything more definite can be said about learning institutions in ancient India.

In the normal course of events, interaction among various shades of thought, methods, and techniques might have led science to higher stages of development. However, the gradual conquest of the country by invaders from west and central Asia injected discontinuity into the old tradition. The invaders brought with them different languages – Arabic, Turkish, and Persian – as well as scientific knowledge, methods, techniques, and concepts of totally different civilizations. Much of that imported scientific knowledge included elements from Indian science.

There is some evidence to suggest that a large number of scholars went out of India to courts of various feudal kings in west and central Asia.[8] It would be interesting to study the ways in which ideas, their synthesis, and their evolution were spread among different civilizations during the medieval period. It would, for instance, be fascinating to know the Indian ideas that were incorporated into the medieval Arabic and Persian scientific traditions of west and central Asia; to see how they further developed as a part of the scientific and intellectual development of these civilizations; to trace the form in which they returned to India; and to discover the impact they had on Indian tradition after coming full circle. These studies must be made before we can fully understand the evolution of science in India.

A major impact on the subcontinent was the introduction of each invader's language – first Arabic and Turkish, later Persian – as the language of administration. This, obviously, created a barrier that effectively prevented communication to all segments of society and so retarded the development, and especially the dissemination, of science. Added barriers to synthesis of the older and the more recent scientific traditions were social, political, and religious differences within Indian society.

This, however, does not mean that there was no communication between the two traditions and that translations from one linguistic group to

[7] History and Culture of the Indian People. Op. cit.
[8] Sarton, George. Op. cit.

another were not carried out. In fact, there is evidence to suggest that a large number of translations were made from Sanskrit into Arabic and Persian, and vice versa. For example, the Unani system, as it was brought from west Asia, borrowed a large number of drugs and even a few concepts to modify considerably the practice of medicine in India. This borrowing, however, was ephemeral and never reached a level at which a synthesis between the Ayurvedic and Unani systems could create a basis for more organized and evolved medical practices. The two still exist as rivals, and a third one has been added – the allopathic. Instead of being considered as ancient, medieval, and modern systems of medicine, they are thought of as contemporary.

There is evidence of considerable scientific activity during the medieval period.[9] There was some development in geometry and geography (previously nonexistent). Chemistry and metallurgy as a part of the craftsman's tradition progressed,[10] as did the introduction of new plants and animals, together with knowledge about their cultivation and breeding. However, the methods and techniques of acquiring knowledge remained limited to observation and analysis, and the next logical step – to carry out experimentation and develop it as an explicitly recognized technique – never took place. No significant concepts or generalizations seem to have emerged. The philosophical outlook remained dominated by religious overtones. Consequently, the differences between ancient and medieval sciences continued to intensify and compete with each other. Both seemed to develop only marginally and never to a stage at which institutionalization of education and methods of research were achieved, as in Europe.

The modern period brings another sharp break in the tradition, with conquest of the country by the British, who introduced modern science that was in opposition to the two earlier traditions and was again in a foreign language.

Modern science came to India at a stage of its development that is characterized by a radical change from the ancient and medieval sciences. Newer branches of science emerged, considerable information was accumulated, and experimentation developed as a full-fledged and refined technique. The language of science took definite shape, institutions evolved, and technology made a decisive breakthrough. In addition, science as a philosophy, a social viewpoint, and an intellectual attitude had scored

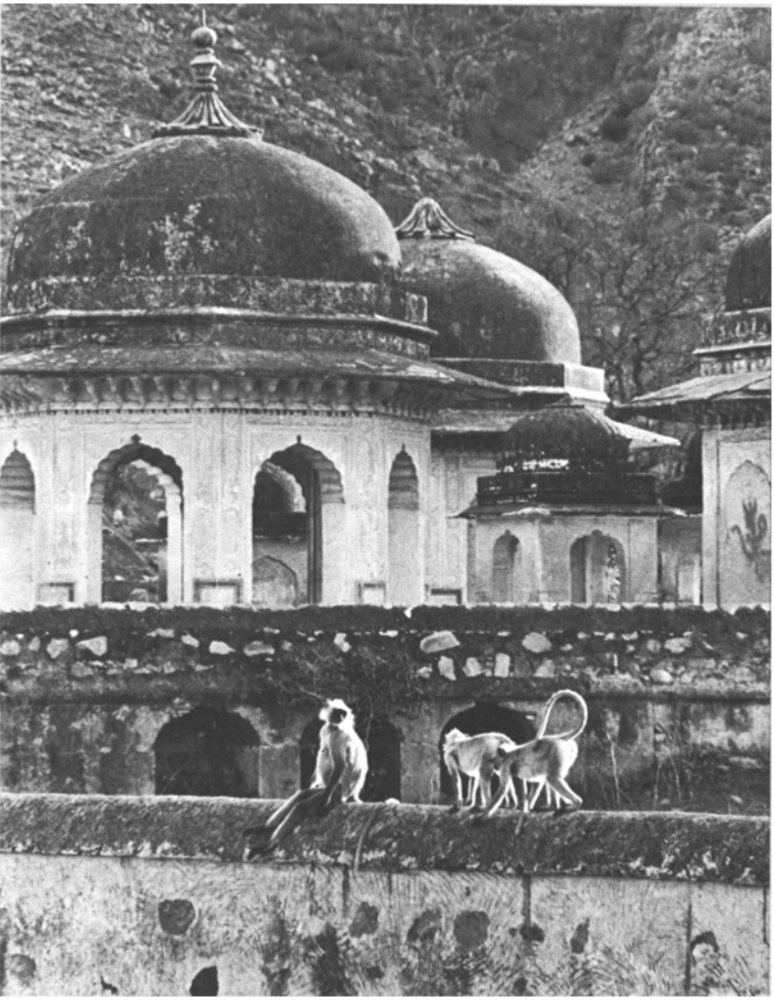
[9] This evidence is based on the number of manuscripts available in the medieval period. They have not been analyzed in detail, but the contents suggest the conclusion. The bibliography of this is in manuscript form and is under process for publication.

[10] Rây, Priyadaranjan. History of Chemistry in Ancient and Medieval India, Incorporating the History of Hindu Chemistry by Prafulla Chândra Rây (Calcutta, Indian Chemical Society, 1956).

MAGNUM / MARC RIBOUD

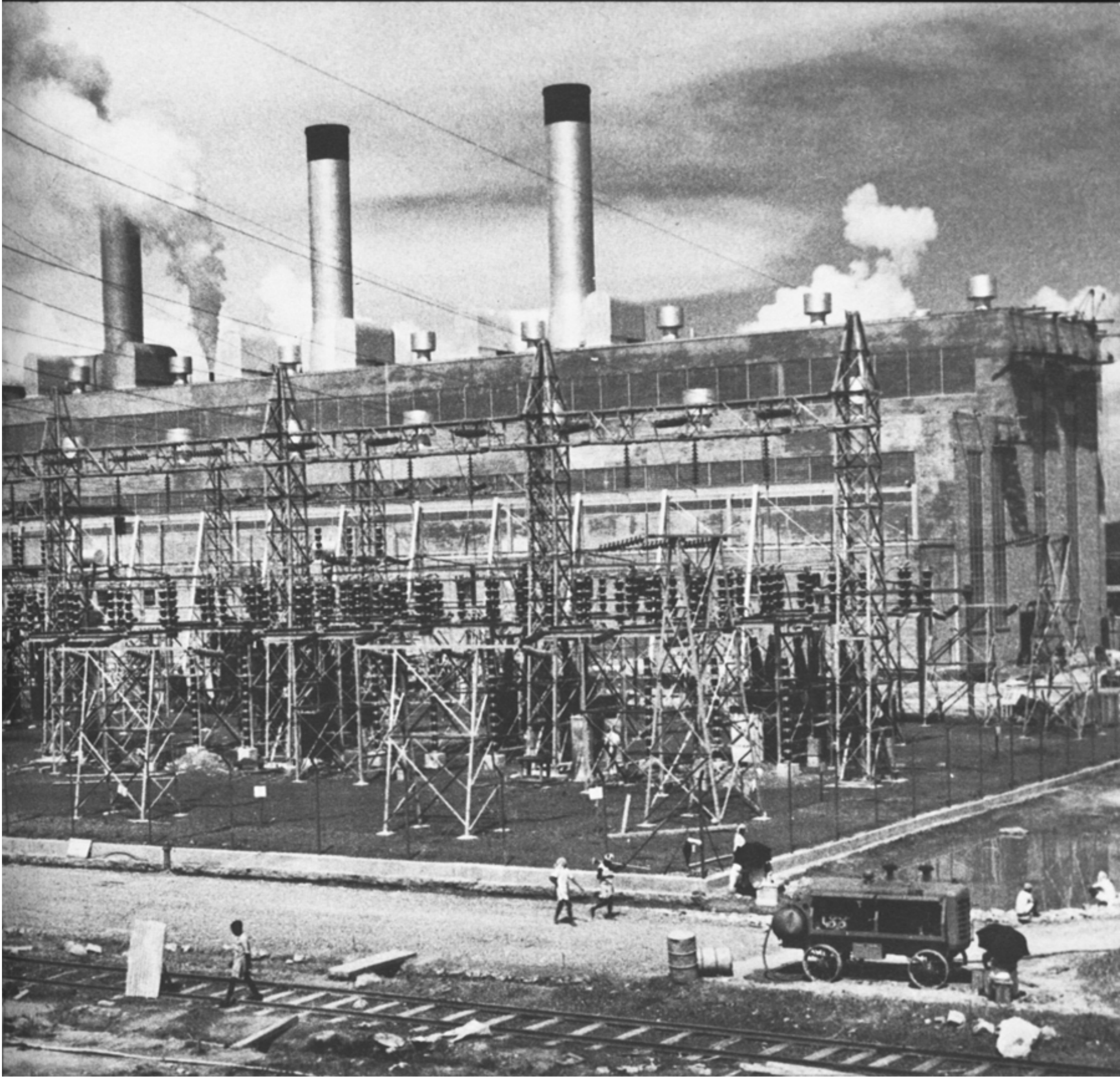
Corbusier-designed buildings and an old lean-to form striking contrast in Chandigarh, India.
In 1965-66 India's mills produced more than 8 billion yards of cotton goods for the world.

GOVERNMENT OF INDIA TOURIST OFFICE

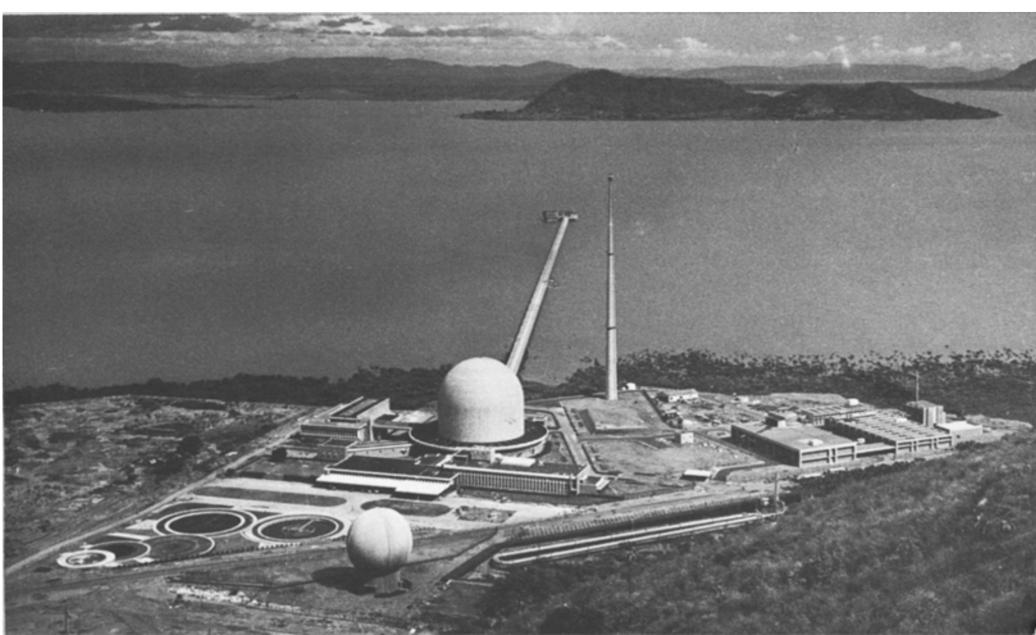


Deserted palace of a feudal lord, left, is in northwest India. Another palace now houses the Central Food Technological Research Institute in Mysore, below.

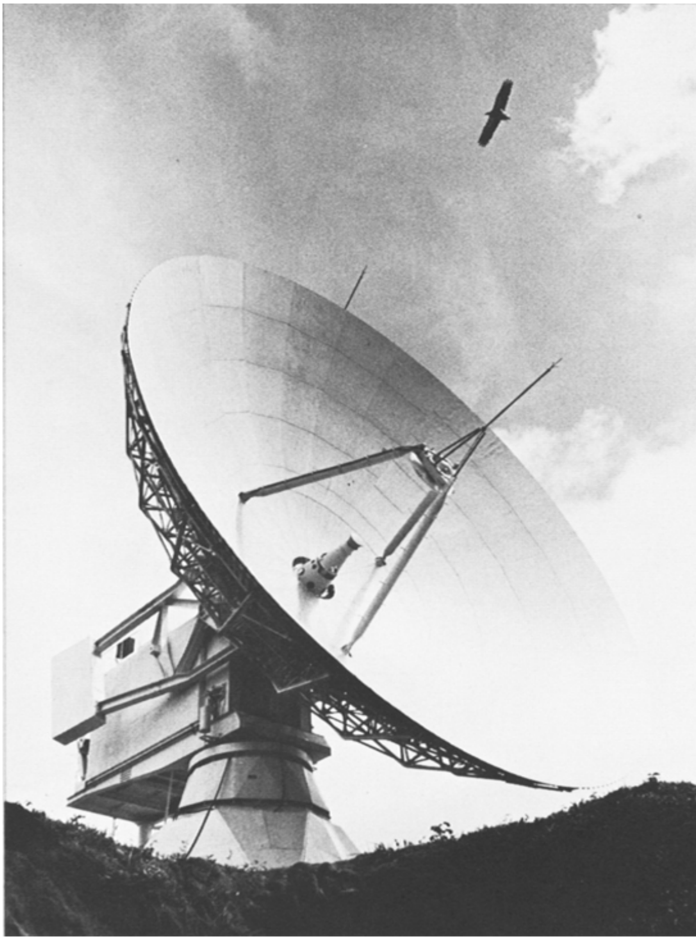
Bokaro power house, right, and the Bhabha Atomic Research Centre at Trombay, below right, which overlooks island of Elephanta, reflect Indian technology.



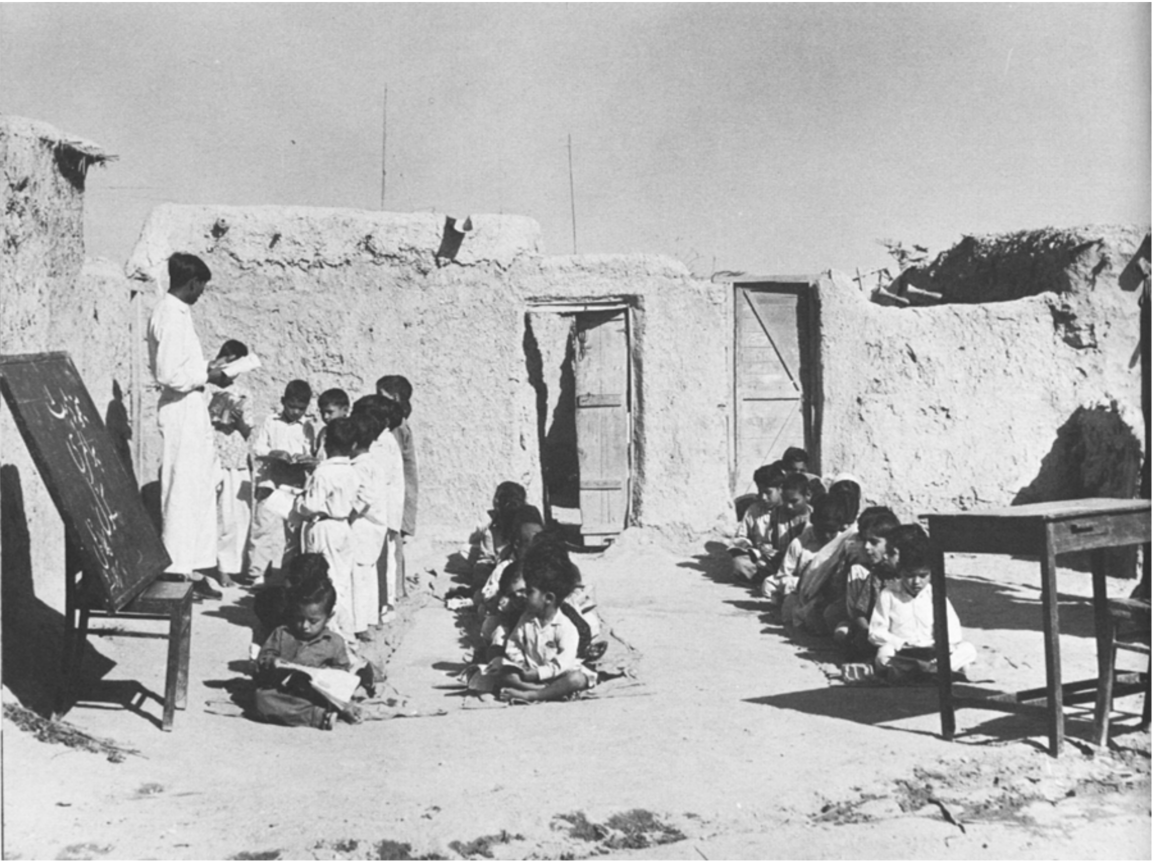
GOVERNMENT OF INDIA TOURIST OFFICE



Jai Singh Observatory, never used efficiently, is above. At far right are the antenna and parabola at Centre for Research and Training on the Use of Satellite Communications, near Ahmedabad, India. Below is the National Physical Laboratory building, at New Delhi.



MAGNUM / CARTIER BRESSON UNITED NATIONS

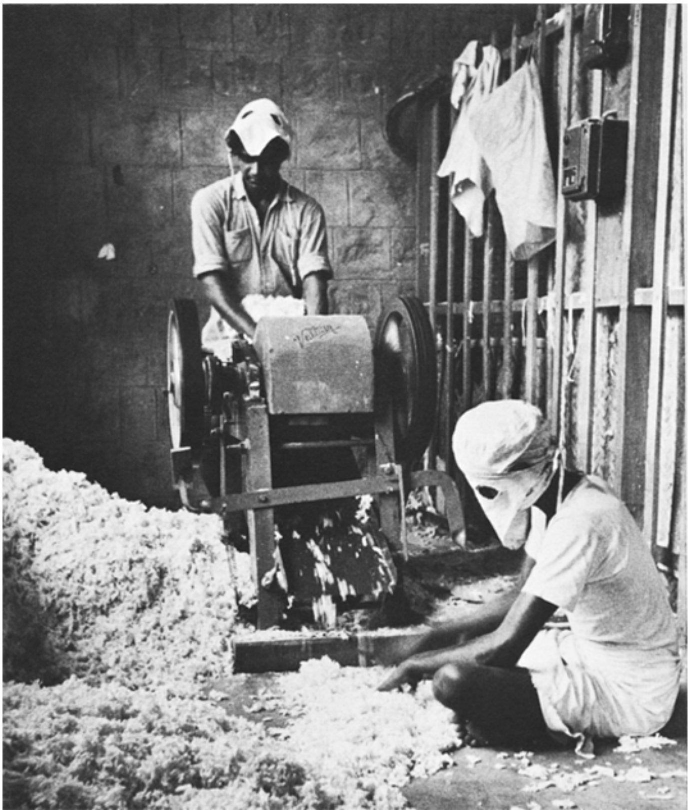


MONKMEYER / FUJIHIRA

Outdoor village school in Pakistan is the antithesis of the modern buildings and facilities

Students at Gandhigram, a rural education and research institution in south India, sort pulp, right, for village industry paper-making process. Assembly line at the Hindustan Motors plant in Calcutta is at far right.

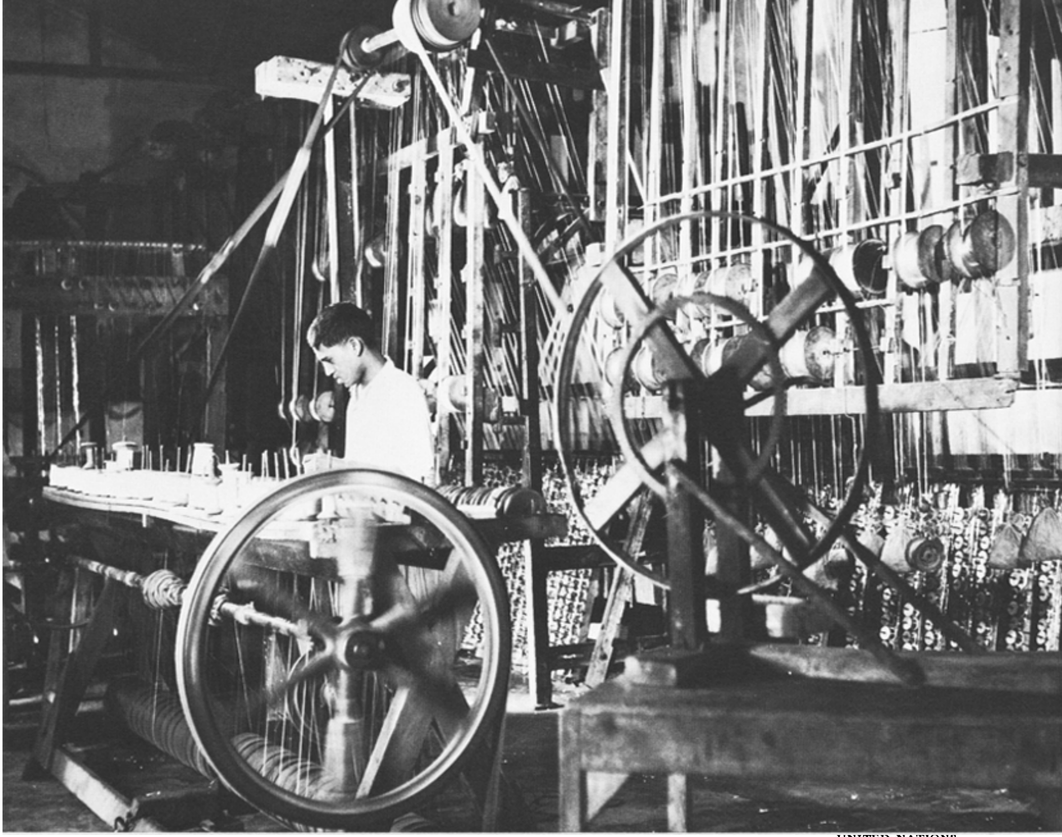
FORD FOUNDATION / HOMER PAGE



FORD FOUNDATION / ERNEST KLEINBERG

that are now becoming available to high school students such as these, above, in Karachi.

MONKMEYER / LANKS


UNITED NATIONS

Looms for ribbon factory, above, were built by villagers; output is sold in New Delhi. Below, extension worker from Central Leather Research Institute gives instruction to village workers.

Y. NAYUDAMMA

a decisive victory over other modes of thinking. It was introduced in its modern form as a fully developed system, without roots and traditions. Its change from the earlier periods of science was so radical that it was not easily understood and assimilated. The new language made this process still more difficult. Consequently, it aroused either awe or hostility as a "British thing," alien to the Indian tradition. Therefore, once again the effort became one of choice rather than of synthesis.

Not surprisingly, that choice was influenced by India's cultural inheritance. Unlike Europe's relation to Greek tradition, the process reinforced the religious, mystical, and philosophical tradition as against the rational and scientific. The endeavors of Raja Sewai Jai Singh of Jaipur in the eighteenth century throw some light on the nature of nonassimilation of the new tradition of science. He was charged by the Delhi King, Muhammad Shah, with reforming the calendar, as the then-current calendar was causing considerable confusion. Jai Singh collected information on latest developments by sending out emissaries and by inviting European scholars to India. He constructed observatories at four places to make comparative observations, and designed new masonry instruments to obviate the defects of the ones that then existed. The approach was systematic and apparently scientific. Yet only the tables of de la Hire were utilized; the work of Copernicus, Galileo, and Newton went unnoticed.[11] To miss them was to miss the entire scientific revolution which had taken place in Europe. This attitude continued in later scientific developments in India.

Another point worth emphasizing is that knowledge of the English language was limited to a small group associated with the rulers. This limitation was a significant one, not as in Europe where science made a break with classical languages and reached the people in disseminating scientific information and ideas. There were three major consequences of this linguistic containment. First, the Indian languages did not develop precise expressions and vocabularies to express new ideas. Therefore, they remained medieval in outlook, overloaded with mystical and ambiguous vocabulary that was emotional in its appeal. This helped to perpetuate a superstitious, antiquated outlook.

Second, the new knowledge, which was available as a result of scientific research, could not reach the artisans and craftsmen, draw them out of their stagnation, and lead them to expand old industries and develop new ones.[12] This may also explain to some extent the nonutilization of research in many fields in India even to this day. The languages of science and of those who use the results of research are quite different.

[11] Soonwala, M. F. Maharaja Sawai Jai Singh II of Jaipur and his Observatories (Jaipur, Jaipur Astronomical Society, 1952).

[12] Râу, Priyadaranjan. Op. cit.

Third, when scientific ideas were limited to a privileged few, the social and intellectual dialogue could not take place on a scale sufficiently large to make a breakthrough. In the absence of such a dialogue, the scientific outlook could not permeate the fabric of Indian society. In Europe, on the other hand, such a dialogue had considerable impact on all aspects of life.[13] The containment of science in India meant that social attitudes, outlooks, and reform movements looked backward for support and sustenance – a situation that still obtains.

A look at the history of science in India shows that efforts have been limited to asserting the great Indian attainments in individual branches of science and to seeking the germs of modern ideas in various fields of science in the past. By comparing and contrasting the Indian developments with contemporary and later developments elsewhere, an attempt has been made to glorify past attainments.[14]

Science in India, therefore, has developed without the appreciation of a new intellectual and philosophical framework, without a continuing dialogue with social thinking, and without an effort to evolve a viable tradition by rejecting medieval and ancient religious philosophies and ideas. Lacking the support of an extensive industrial and technological movement, it has become isolated and almost totally dependent upon the government. In other words, science did not develop as a widespread intellectual and social movement, changing the very character of Indian society.[15] It did not develop a set of intellectual values to which the earlier scientific traditions could be meaningfully related as the basis for further development.

Science was taught in the universities, but it was taught in English, thus intensifying its alien character. This led to a dichotomy in the attitudes of Indian scientists toward the natural world and society – both as scientists in the laboratory and nonscientists outside it. The requirements of colonial government in all its ramifications made science government-dependent and greatly limited its scope. This may also explain the impact of bureaucracy on science today, and the dependence of scientists on the administration.

Perhaps for these reasons, the steam engine and electricity, introduced in India along with other technical innovations soon after they were developed and used in England, did not make the social and intellectual impact they did in Europe.

One man in India, more than anyone else in modern times, was conscious

[13] Sarton, George. Op. cit.

[14] Seal, Sir Brajendranath. The Positive Sciences of the Ancient Hindus (London, Longmans Green, 1915; Reprinted by Motilal Banarisidas, Delhi, 1958).

[15] "Science and Cultural Values and Historical Analysis," *New Orient*, 1960, Vol. 1, pp. 19–22.

of the isolation of modern science from Indian society, and sought to make an effective contribution by emphasizing the scientific tradition, outlook, and temper, by using science as an instrument of change, by employing the the scientific method in planning to control and shape the development of the country, and by laying a foundation for science through creation of a chain of research laboratories. Nehru's full contribution to science has yet to be studied and understood. But there still remains the task of evolving a scientific tradition, of linking ancient, medieval, and modern scientific thought, and of creating a set of national values around which ideas can be crystallized and possibilities for further development organized. This is the problem confronting science in India and, in fact, in all the other developing countries throughout the world.

Social and Intellectual Setting for Scientific Inquiry in India

P. K. KELKAR

THERE IS LITTLE DOUBT that science and technology will have to play a most significant role in the great transformation that began in India in 1947 and has developed on a comparatively large scale since then. The progress already achieved appears reasonable in comparison with pre-1947 standards. Yet, if one makes an over-all estimate of the present situation in relation to what might be considered the necessary ingredients for a modern technological society, one would be forced to the more-or-less obvious conclusion that there is a wide gap between what is and what ought to be. A systematic analysis of all that is involved in such a complex situation is not possible here, but let us focus on some of the less apparent aspects.

The mental qualities needed to sustain genuine scientific endeavor have been manifest in all societies, at least to some degree, at various times in the past. Nevertheless, it is true that the industrial revolution in the modern sense started in Europe in general and in England in particular during the late Middle Ages and early Renaissance periods. It is reasonable, therefore, to assume that something characteristic about the revolution was lacking in the Chinese and Indian civilizations. The most important factor to be kept in mind from the Indian point of view is that the industrial transformation now being attempted is not a natural development of past achievements. It is not an evolutionary process but is, in essence, a revolution.

At this stage it would be useful to refer briefly to some of the beliefs and reactions that have been broadly characteristic of Indian thought for several thousand years. It seems to have been accepted that, in general, individual existence is associated with suffering. The basic preoccupation has, therefore, been a search for that knowledge – or recipe, if you will –

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by which the individual can, through his own efforts, overcome the basic cause of this suffering and achieve liberation from bondage. The most significant aspect of this belief is that each individual is held fully responsible for what he does or what happens to him.

The law of karma, which has made such a deep impression on the minds of the Indians, is a kind of compilation of all the deeds with which the individual is associated directly or indirectly, at either the conscious or the subconscious level. Each individual thus carries this burden endlessly, through successive births. The main purpose of existence, then, is to find who oneself really is and, in the process, achieve freedom from the necessity of being reborn again. Without going into either the philosophy or the metaphysical principles underlying some of these beliefs, it might be useful to examine how the mental attitude of an average person is affected and how certain patterns of social behavior and customs become more predominant.

First of all, each individual tends to be an introvert in relation to his environment. He meets the challenge of his own cravings and aversions, not by trying to modify the environment through his own efforts and the efforts of others, but by working within himself at the psychological level and trying to modify the reactions of his mind to the world around and within him. Then, again, because the individual is made responsible for the kind of life he leads, there is little support for secular institutions organized for the benefit of large groups of people.

Each person's daily life is governed by a host of rituals that have the force of moral law. Little initiative is left to him, as the basic social structure tends to be static in the interest of security, continuity, and permanence. In fact, aversion to environmental change becomes the automatic response. Space and time are too insignificant to affect events. Perhaps it is no accident that India has no recorded economic history in the modern sense of the word.

All of this indicates the kind of psychological background that has been inherited by the ordinary individual. At the other end of the spectrum, there have always been those who have demonstrated that it is possible to modify the mind by appropriate efforts. As a result of these efforts, the divine element of which the mind is constituted – at least in part – becomes manifest both to the individual's mind and to other minds as well. The mind so purified can identify itself with what is to be known, so that the distinction between the knower and the known disappears. One does not acquire knowledge; knowledge comes to one. Real knowledge is thought to be not amenable to a conceptual or analytical approach; it comes through perception. Complete knowledge is the result of total awareness.

These are some of the psychological barriers to the proper acceptance of the scientific attitude and its conscious application to the understanding of nature. The emphasis in the modern world of science and technology is essentially on providing optimal benefits to society as a whole. This makes it possible for the individual to do his best for himself only insofar as his best does not clash with the compelling needs of a complex social organization.

The Indian approach, on the other hand, has been to give the individual as much opportunity to develop his potentialities from within as would be consistent with over-all social needs. The limitation of this arrangement is that it is necessary to contain the rate at which changes are made in relation to the environment. In other words, the Indian philosophy is to make it possible for an individual to achieve salvation through his own efforts; the modern approach seems to be moving toward the possibility of achieving salvation for a large number of individuals by combined efforts.

No matter which way one looks at the problem, the setting for scientific inquiry in India depends, in the final analysis, on the individual's attitude toward and awareness of the natural world around him. This has a direct bearing on our present attempts to achieve a quick and extensive technological transformation in India.

This discussion should give some idea of the complexity of bringing about a scientific and technological revolution that is acceptable to the country as a whole and can become a part of our cultural heritage. Real and self-sustained changes can never take place unless a way can be found to come to terms with the cultural context of society at the psychological level. Time and again the Indian genius has proved that, when challenged at the roots, a total conversion does not occur. Rather, there is acceptance through assimilation, so that what exists is enriched but not altogether replaced. It may not be out of place at this stage to suggest some steps that would help to achieve a scientific and technological revolution.

The impact of science and technology on modern India has unquestionably been substantial, but it has not been revolutionary, in the sense of a political revolution such as India has experienced through her struggle for independence. A scientific revolution of that magnitude can only be achieved through large-scale cultural and psychological changes. Well-planned steps must be taken to bring about the changes in a measurable period of time. They must also be undertaken in such a way that the inevitable stress and strain accompanying an all-embracing and rapid transformation will not destroy the fabric of society. India has reasonable access to the massive accumulation of scientific knowledge and experience. To be able to derive adequate benefit from this source, however, the intellectual and imaginative effort required is of almost the same magnitude as that needed for the creation of new knowledge and experience.

The most challenging problems are associated with four facts of life in contemporary India. First is the size of the population, which is growing at an alarming rate. Second, one effect of technology has been the creation of a worldwide uniformity of individual needs and desires. In India, this has produced an explosion of expectations, still unfulfilled. This, in turn, has been reflected by widespread feelings of deprivation and disappointment among the majority of the people. Third, multiplicity of languages and difficulties of communication through the written and the spoken word are obstructing the free flow of relevant ideas and information, which alone can bring about and sustain the requisite changes. Fourth, accumulation of knowledge has reached enormous proportions and is accelerating so rapidly that the mere task of keeping abreast of current scientific and technological developments is a highly complex and difficult undertaking.

These represent particular problems for a country like India, which is far behind industrially advanced countries in many fields of science and technology. The most effective – and perhaps the only – way the complexities can be solved even partially is by bringing to bear those sophisticated and advanced techniques and devices that are the most difficult for scientifically underdeveloped nations to utilize on a widespread basis.

It is obvious that unless a sufficiently large number of persons with well-trained and highly competent minds becomes available it will not be possible to deal in depth with the complex problems facing India. Even at the highest intellectual level, men can become effective only in relation to their particular gifts, temperaments, and values. It has been argued that, in its early stages, the English industrial and scientific revolutions reflected the religious and ethical tone of the period. The asceticism of Calvinistic Puritanism created a favorable attitude toward scientific research and technological activity. In 1663, forty-two of the sixty-eight Fellows of the Royal Society were Puritans. Further, in mining and foundry establishments and, later, in the textile industry, Puritans played a prominent part.

The relevant point here is that attitudes toward science and engineering were, in the last analysis, an outward expression of inner convictions. Many scientists as well as technicians in seventeenth- and eighteenth-century England were deeply devout men. At the psychological level, the inner power that created and sustained the Industrial Revolution had its source in religious beliefs. If, therefore, science and technology are to take deep roots in India, a large number of gifted individuals must pursue science as an enterprise intimately connected with the lives of men and women, and not as an abstraction. Merely being engaged in scientific activity is of little significance without a genuinely scientific attitude of mind and a deep feeling for the relation of science to nature and life.

An industrial revolution is essentially a revolution in power. The power of technology helps to relieve the individual of both physical and mental drudgery. The machine is taking over a good many complicated processes, and the shift from physical human labor to sophisticated intellectual activity is posing the most significant challenge of modern times.

In India today, the "past" coexists on a large scale with a small-scale and struggling "present." Unless an organic connection is established between the two so that the past can be absorbed into the present without too great a strain on society, there is little hope of a real technological transformation being achieved in this country in the foreseeable future. The most powerful single element in this context is the creation of a large reservoir of intellectual power and its deployment on a wide front. This is an expensive and time-consuming process, but, in the last analysis, it is the price that must be paid for survival as a viable nation in the modern world.

In the past, the physical sciences derived strength from the world of mathematics, and the life sciences, in turn, had a powerful interaction with physical sciences. Science has now begun to enter the world of human behavior and is trying to uncover the inner reservoirs of power and understanding at the psychological level. Science today is as powerful as religion was in the past. Both of them derive their strength from something deep in human beings.

If science, particularly as it begins to explore more systematically the world of human behavior, finds ways of tapping inner reservoirs of power and understanding within the individual, and does so in a meaningful relationship to the religious and social values of the Indian people, India will be able to overcome the many problems confronting her.

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SCIENTIFIC EDUCATION AND RESEARCH

Science Teaching and Research in Indian Universities

B. R. SESHACHAR

THIS ESSAY attempts to explore a few of the many problems of scientific training and research in Indian universities. Because they are not unique to India, the discussion may have some relevance to the situation which obtains elsewhere in the subcontinent and perhaps in other developing countries as well. The difficulties are so numerous that it is impossible to deal with all of them here. For example, there is the general problem of the very rapid growth of the universities in recent years. Then there are more specific problems about the proper relationship between teaching and research, advanced training in science and the tools required, teacher training for the schools, administration of universities, the role of universities in developing the scientific temper of the country, and so on. Rather special to India is the problem of language and the medium of instruction. Any of these could form the subject of a separate essay, but only one or two can be presented here.

First, let us look at the growth of universities in India. This has relevance to virtually all developing countries in which universities are being established rapidly. To say that this growth is phenomenal is an understatement. The first university in India was founded in Calcutta in 1857, and about the same time two others – in Bombay and Madras – were also begun. In 1900, we still had only five universities; twenty years later there were seven; by 1930, ten more had been added. By 1947, when we acquired Independence, there were 25 universities. Today there are 69 universities in India. This number includes some institutions of higher learning deemed to be universities, such as the Indian Statistical Institute of Calcutta, the Indian Institute of Science at Bangalore, the Indian Agricultural Research Institute and the All-India Institute of Medical Sciences in New Delhi,

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and the more recent Indian Institutes of Technology in Bombay, Madras, Delhi, Kanpur, and Kharagpur. Quite recently some universities specializing in agriculture have been added at Rudrapur, Ludhiana, Bangalore, and Hyderabad.

At this point, it should be mentioned that most of the universities in India are maintained by state governments with supporting grants from the central government through the University Grants Commission (UGC), which was established in 1954 on the model of the University Grants Committee in Great Britain. The UGC is an autonomous body intended to coordinate and improve standards of higher education and provide funds for teaching and research in the universities. The Commission itself obtains its funds from the central government, and is charged with the responsibility for higher education and research, not only in the sciences but also in other fields. It is clear, however, that as long as higher education remains a state subject, as it is under the Constitution of India, and as long as adequate funds are not available, the UGC will not be able to discharge this important function satisfactorily.

With the rapid proliferation of universities after Independence, there has been a depression of standards of teaching and research in many universities. Lack of qualified teachers, inadequate library facilities, and absence of essential equipment have been contributing factors. The state governments are anxious to start new universities, as the university has become a state prestige symbol. However, lack of the continued and increasing support so necessary for maintaining a university at its highest level has caused a number of them to work without fully qualified staff and with inadequate facilities. The central government is now contemplating drastic measures for halting the increase in the number of universities.

The situation has, on the whole, caused radical rethinking. The central government has appealed to the states to permit it to handle higher education by making it what is called a "concurrent subject" under the Constitution. Soon after M. C. Chagla, then the Minister of Education, took office, he sent an appeal to this effect to the state governments. Virtually all the states have opposed the idea, for once higher education is out of the control of state governments, they suffer a loss of prestige. Therefore, today many newly started universities are languishing for lack of support from their state governments but are still not permitted to seek and obtain support from the central government. The resulting conditions for scientific teaching and research can well be imagined.

But how does one reconcile the urge for higher education, especially in the sciences, on the part of an increasing number of people, with the maintenance of standards? How does one meet the needs of the many and still keep a place in the front line of progress? How does one teach science and teach it well in a large country like India with rapidly increasing student enrollments every year?

This is the crisis in Indian universities today. While it is acute in all branches of knowledge, it is desperate in the sciences, especially in the natural sciences, where additional demands for equipment and special facilities have made teaching in the universities an almost hopeless task.

Two remedies have been suggested. One of them pleads for an "inter-university division of labor," to prevent an unduly wide dispersal of available resources. First-rate scholars are not too abundant, and it is necessary to conserve scarce intellectual resources. If special departments could be set up or further developed in some selected universities, we might strengthen such centers and at the same time avoid the existence of substandard conditions in many others. These latter universities would have to curtail the range of their operations and specialize in a limited number of fields at the postgraduate level, keeping the subsidiary fields of study at the undergraduate level.

Higher studies and research flourish in an atmosphere congenial to intellectual intercourse. For this to be fruitful, a university needs a minimum number of scholars in the same field. The University Grants Commission has recognized this and has designated a number of "Centres of Advanced Study" in different universities in India. While all or most universities conduct science studies up to the postgraduate level, the advanced centers will be leaders in the field and, through special grants, will be able to attract talented teachers, obtain adequate equipment, and build facilities for advanced teaching and research. This is the first suggested remedy.

The second approach is the idea of "national universities" or "central universities." A few of these, located in appropriate and convenient regions in the country, would be given massive support from the central government. They could reorient their policies to attract both qualified teachers and talented students. To some extent, this has already happened. We have the special institutes, which have already been mentioned, and it seems necessary only to extend this concept to other, less specialized fields.

However, it is important that, in doing either of these, we avoid the other extreme, in which talented teachers would be underemployed or expensive equipment and libraries unused. In a vast and poor country like India, where distances are large and students cannot afford to leave their homes for a university in another state, this can be a problem. In my opinion, however, it is not insoluble.

The second major problem deals with the relationship between teaching and research. The functions of a university have been variously defined, but in pragmatic terms a university may be said to discharge three functions: impart liberal education, prepare students for the professions, and discover new knowledge. While all universities may not be able to discharge all these functions with equal effectiveness or with the highest standards, and while it is possible to underscore the importance of one or another of them, it seems to me that fostering the symbiosis of teaching and research should be one of the hallmarks of a true university. The university makes a contribution to fundamental science as no other organization or agency can. In fact, the state of the universities in a country provides the measure of the health of its science and technology. Teaching and research flourish in combination, and the divorce of one from the other leads to the extinction of both.

In India today, in the context of the rather discouraging picture of university proliferation and the accompanying deprivation of resources and depression of standards, and in view of the meager allotments for scientific research, it seems both necessary and vital to make every effort to assure that university research grows. The following figures indicate how little is, in fact, being done.

Out of the 1964–65 total UGC allotment of about Rs 140 million (something less than $30 million before devaluation of the rupee in June, 1966) to 60 Indian universities, about $4 million went to the natural sciences for teaching and research. Sixty universities and $4 million means about $65,000 for all natural science departments of a university. Distributed over six or seven science disciplines, it means an allotment of about $10,000 each. Under these circumstances, how can we expect the universities to make an effective contribution to the scientific output of the country? Usually, there are several areas of research in each of the sciences, so the difficulties of departmental heads in allocating funds to research personnel can be readily appreciated, as can the frustration of those who receive these meager amounts.

By comparison, the grants available to other laboratories of the country, such as those of the Council of Scientific and Industrial Research (CSIR), the Atomic Energy Commission, and other government laboratories, are munificent. That these latter are engaged in applied research should not be an argument for the neglect of the universities. Certainly it is not government policy to encourage applied research at the expense of basic research and training. Today the plain fact is that resources and men are being drawn away from the universities to these other laboratories. This situation is not peculiar to India. It is happening in many other countries. The general outline presented here should enable us to appreciate that an imbalance between teaching and research and between basic and applied science can lead to serious dissonances in the development of science.

It is not enough to say that the universities are crowded; they are overcrowded in virtually every country. It is not enough to say that they are understaffed, that their equipment is poor and outdated, and that the library and other services are inadequate. It is necessary to improve them; to recognize that their well-being and quality contribute to the well-being of science as a whole; to understand that they complement effectively the scientific work of other institutions; and, above all, to be realistically aware that they discharge the function of teaching – which no other agency can. Only the universities can take on the function of transmitting knowledge. Only they can assure the inheritance of science, and if we do not make sure of this inheritance, we shall find ourselves in a truly sterile world. The fabric of science requires the warp and woof of teaching and research. In the absence of either one, the fabric must remain unwoven.

Development of Scientific Research in India and the Role of the Council of Scientific and Industrial Research

S. HUSAIN ZAHEER

SCIENCE AND SCIENTIFIC RESEARCH in India, although there had been some isolated but remarkable individual achievements, hardly existed before Independence. Even in the country's score of universities, the standards of teaching and the research facilities were wholly insufficient. The main effort, however inadequate it may be even now, really started after 1947.

At that time it was decided to establish the Council of Scientific and Industrial Research (CSIR) to give scientific and technological support to the country's industrialization and economic development. It was also generally realized that industrial development must be associated with agricultural development. (Indeed, agriculture may well be regarded as a form of industry, needing powerful engineering and scientific support.)

During the Third Five-Year Plan the total investment in science and scientific research in India was roughly 0.3 per cent of the gross national product. It had been recommended that in the Fourth Five-Year Plan this investment be increased to a minimum of one per cent of the gross national product, which would have meant doubling the existing effort if the recommendation should be followed, although that does not seem likely.

Scientific research in India at present is organized under six major groups: universities and advanced centers of studies; autonomous councils such as CSIR, the Indian Council of Agricultural Research (ICAR), and the Indian Council of Medical Research (ICMR); the Atomic Energy Commission; the Defense Research and Development Organization; laboratories under the various ministries and departments; and, finally, research

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laboratories in both the private and public sectors of industry. Working conditions, facilities, organizational patterns, and methods and traditions of research laboratories vary considerably in each of these categories.

The Council of Scientific and Industrial Research constitutes the mainstream of civil science research. It began with a budget of about $100,000 twenty-five years ago. In 1962–63 the budget had grown to about $16 million. Owing to the exigencies of national requirements and economic pressures and to the needs and demand for larger support of science, its budget has more than doubled during the next three years, and in 1966-67 the operating budget was almost $51 million annually.

CSIR is a registered, or autonomous, society, but it receives its grants through the Ministry of Education on the basis of parliamentary appropriation. The Minister of Education is its Vice President and the Prime Minister its President. The Council itself, however, decides all its own policies and programs through the Director General, who is a scientist and the chief executive officer of the Council, through its governing body, and its Board of Scientific and Industrial Research.

During the last four years, the most significant change which has taken place, and which distinguishes the CSIR from other research organizations in the country, is the involvement of the scientific community in the decision-making machinery of the Council. In all CSIR bodies that plan research programs, university scientists, independent research workers, research workers from other government departments and industry, and administrators participate in the different aspects of decision-making at various levels. The representatives of these groups take part in the formulation of research programs, recommend expenditures to be made within the sanctioned budget, and participate in establishing rules and regulations at the institutional and national levels to improve working conditions of the scientists in CSIR.

The efforts made by CSIR to involve the entire scientific community, representing different disciplines and institutions, in formulating policies and executing them should be emphasized. The decisions represent a consensus and a cross-section of the thinking of the scientific community as a whole. In addition to directly employing over 3,000 scientists, the CSIR depends on the advice and guidance of a much larger number of scientists throughout the country. They are members of its research councils, of executive councils of individual laboratories, of research committees in different disciplines, and of the Board of Scientific and Industrial Research and the governing body of the CSIR.

As a result of this structure, the Council has been able to initiate programs that have effectively molded scientific policies and thinking and that have also had wider repercussions throughout India. This has given vigor to the CSIR, a vigor that is unique in the country. By way of contrast, until very recently only one member of the four-man Indian Atomic Energy Commission was a scientist.

During the last four years, the CSIR made a major effort to break down the isolation of science and to project it as a major instrument of social and economic growth. It has initiated new thinking in planning scientific research, utilization of manpower, and working conditions of scientists. It has sought to attract young minds to research by awarding a large number of fellowships, and to bring Indian scientists back from more advanced countries. Promoting the utilization of results of research has also been a major area of change. I will discuss these developments in greater detail later.

The 35 CSIR laboratories and institutions are of four types. There are subject laboratories, such as the National Physical Laboratory and the National Chemical Laboratory; commodity laboratories in fields such as glass, leather, food, and petroleum; and multipurpose laboratories, such as the Regional Research Laboratories in Hyderabad, Jammu and Srinagar, Jorhat and Bhubaneswar. The fourth type includes such cooperative industrial research associations as those for textiles, jute, and silk.

The directors of individual laboratories have a large measure of autonomy in the development and execution of their work. Their broad policies and larger programs are decided by an executive council comprised of scientists and technologists who represent a cross-section of the scientific community. Technical groups attached directly to the CSIR carry on specific activities that arise in the functioning of these laboratories in the context of the national role of the CSIR. These activities are conducted under various directorates, organizations, and units; they cover such fields as publication and information, documentation, translation, and photoduplication services; facilities for the design and fabrication of pilot-plant equipment; industrial liaison and contact with other research groups; manpower and technical personnel; survey and planning of scientific research; defense coordination; and the popularization of science in English and Indian languages.

Against this organizational background, three major and significant changes have occurred in the last four years. They should be emphasized and discussed in some detail. These are the abolition of hierarchy, the decentralization of power, and the project orientation of research. All are interrelated, and among them they have brought about a major increase in CSIR productivity. Their full impact will be felt in the weeks, months, and years to come.

Until recently, a laboratory was organized into various subject and service divisions. These divisions were manned by nine categories of scientists, ranging from junior laboratory assistant to deputy director. The difference in qualification requirements were marginal, as were the differences in salaries between one grade and the next. But the over-all differentiations in status were very great. There was a world of difference between, say, an M.SC. who was a junior scientific assistant and an assistant director who was also an M.SC. Reports and other official papers moved up and down with due deference to those higher up. Usually, it was only those higher up who made decisions. Scientists gave undue thought to their promotion and moved from one position to another for an additional few rupees, each time disrupting the work they were doing.

Recent decisions have taken the first steps in the abolition of this hierarchy. Every worker is a scientist, and there are no other designations. Merit promotions are given in recognition of distinguished work, so that to get a higher salary a scientist need not wait for the promotion or retirement of his senior officer or the creation of a new post. In addition to merit promotion for distinguished scientific effort, the work of a scientist is to be reviewed every five years and, if it has been satisfactory, he is promoted in his own post. Thus a scientist competes only with the quality of his own work—a circumstance which should do away with many unhealthy rivalries and jealousies.[1]

Project orientation of research work eliminates hierarchy in the laboratories in still another way. The head of a division is no longer the leader of every project and no longer represents all the workers in a discipline in meetings held within and outside the laboratory. The most senior member of a group of workers is leader in some of these meetings and an associate in others. In this way, the young workers who become project leaders will learn to think clearly and to lead with confidence, criticizing the work of others and in turn accepting criticism of their own work. This should result in a two-way "intellectual traffic," unlike before, when the younger workers, deprived of responsibility, would only criticize the senior people who, in turn, would only "lecture" to their juniors. The net effect will democratize science and help to create a better research atmosphere in the laboratories.

In addition to these steps, other changes have been made to decentralize

[1] In the laboratory for which I consider myself primarily responsible (the Regional Research Laboratory at Hyderabad) there is always a team of sociologists studying and examining the relationships among the senior scientist and his technical assistants and junior colleagues. One result may be cited. For fifteen years, all the staff of the Hyderabad Laboratory—from director to porter—ate together in the canteen. No seats or tables were reserved, but a corner of one bench was vacated for the director as soon as he appeared. This was an extremely successful social experiment. Obviously, as Director-General, I could not issue an order to all CSIR laboratories to do the same, but I can hope that, by example, if not by precept, the practice will grow.

the powers of the headquarters of the Council so that the directors of individual laboratories can make on-the-spot decisions. The present policy is that, insofar as possible, the scientific committees and the executive councils of the various laboratories should make decisions regarding their research programs and financial involvement within previously-established budget ceilings. The CSIR headquarters concentrates on helping the laboratory directors through coordination and development of over-all research policies.

The directors of all the national laboratories now meet regularly every year and arrive at broad decisions on CSIR policy and organization. In addition to these democratization measures, the research workers in a particular field are also encouraged to meet and work out policies regarding their particular field of work. For instance, in May 1963 information scientists met to develop plans, including working conditions and their programs of activities. These plans were accepted by the directors' conference and the governing body of CSIR, and have now become the general policy of the Council.

One of the major problems facing any country is scientific manpower, the availability of which determines to a very large extent the quantity and quality of scientific effort. This applies equally to developed and developing countries. The principal elements of the problem for developing countries are: training sufficient numbers of scientists for special fields; attracting young people to research and creating conditions that will encourage them to remain in it; and, of course, encouraging trained scientists not to leave or, if they have left, to return to their country.

By giving junior and senior fellowships, the CSIR has attracted a large number of young scientists to research. Phenomenal progress has been achieved in two years: only 465 fellowships were available in 1962; 1,500 young scientists were receiving support in 1964. One can imagine young scientists' confidence in the future when anyone who gets a first-class science degree and wants to carry out research is able to do so without difficulty.

A special word should be added about the relationship of CSIR to scientific work in the universities. It is sometimes suggested that CSIR has seriously weakened science at that level.[2] However, it has not drawn a large number of scientists from universities to top positions in CSIR laboratories. When the laboratories were started, only one director – Dr. Krishnan of the National Physical Laboratory – came from a university. The other labora-

[2] *See*, for example, Bhabha Homi J., "Science and the Problems of Development," *Science*, 1966, Vol. 151, pp. 541–548. In regard to this particular point, Dr. Bhabha's article is not factually accurate.

tories were headed by outsiders – foreign scientists from the United States, Britain, and France – and are now directed primarily by scientists who themselves have been trained in the CSIR laboratories. Subsequently, it has been rare for a university department head to become a laboratory director. Of the 35 directors of laboratories, only four have been heads of departments in universities and that, obviously, does not constitute any significant depletion of university personnel.

On the other hand, scientists trained and working in CSIR laboratories have frequently taken university positions. The facilities for research at the national laboratories are freely available to neighboring universities. Most of the laboratories have direct working arrangements with nearby universities and give support to research and teaching in various departments, and laboratory scientists give regular courses of lectures or teach formal classes. On balance, the CSIR laboratories have contributed greatly to the growth of scientific research in the universities.

The brain-drain – that is, the migration of scientists from developing to advanced countries – has reached alarming proportions. In an effort to deal with this situation, CSIR has developed a scheme that is unique in India and was actually started in 1958 under the directive of Prime Minister Jawaharlal Nehru in an effort to bring back scientists then working abroad. CSIR tries to contact Indian scientists working outside India and prepare a national register of them. Then positions are offered if they will come come back to India. In 1962–63, about 180 returned. Now that number is nearly 1,000 a year, and the response is increasing all the time.

Once the scientists return to the country, only 2 per cent go abroad again. Nearly 70 per cent find permanent positions within a year and the rest within two years. One great hindrance to young scientists returning to India, it was found, was the long delay and frustration in locating permanent positions *after* their return. The CSIR has now taken the responsibility of finding a scientist a temporary position even *before* he returns. This has proved to be a major factor in the success of the CSIR "Scientists' Pool."

To give young scientists full opportunity to reach the top and to give research facilities to senior workers who have reached the retiring age, the CSIR has promoted two other schemes that have paid good dividends. Today 30 scientists who retired from their posts in other institutions, giving place to younger men, are able to carry on their research in CSIR, as do six emeritus CSIR scientists.

The CSIR has also been supporting special research projects – 562 today in contrast to only 371 in 1962. These projects are in universities and other centers, and give training opportunities to young workers, at the same time furthering research. Recently, the CSIR asked the research committees responsible for allocating grants to assess critically the role these projects have played in the organization and development of new research for national requirements.

Utilization of the results of research is a major problem in every country, irrespective of its level of development. This will continue, for a number of complex and difficult situations are involved.

Recently the CSIR has taken steps to identify industrial problems, so that research directly related to them is given priority. It has also strengthened liaison and consultant activities to develop a two-way flow of information and to establish collaboration and cooperation with industry. For example, scientists, technologists, and engineers from related industries sit on the scientific advisory committees and the executive councils of laboratories, participating actively in the formulation of programs. In addition, a special office has been established in Delhi to make research available to industry, and liaison units with major industrial manufacturing associations have been set up.

As another example, a large conference of scientists and engineers from public and private industries, from government departments, and from universities and research laboratories was held in December 1965. It was a great success, and there is now far more appreciation than ever existed before of the need for scientific work and indigenous technological development in India.

It has also been decided to actively encourage operations research (which could also be termed efficiency studies) at all levels – in the individual laboratories and at CSIR headquarters. This branch of science had been neglected, although it is largely responsible for the productivity revolution in the advanced countries.

Lack of design and engineering facilities has been the major bottleneck in using results of research. Earlier reports of CSIR reviewing committees pointed this out, but active steps were taken only recently. CSIR has now established a design and engineering group to help design and fabricate equipment. It is hoped that, as it grows, this organization will considerably increase the use of research results.

In this brief essay, I have described some lines of new thinking and new departures in the work of CSIR. Obviously, this is a growing organization alive to the needs of India, sensitive to the demands of the times, and abreast of the latest ideas for using scientific research as an important instrument for development. In this effort, we welcome collaboration and cooperation with scientists in other countries, including our colleagues in Pakistan, in establishing centers of scientific excellence and other programs to advance human welfare through the application of scientific knowledge to the social and economic needs of mankind.

The Industrialization of Developing Countries: Science, Engineering, Technology, and Other Aspects of Industrial Growth

H. E. HOELSCHER

THE EMERGENCE of new nations with diverse and unfamiliar cultures and values, the rapidity and unevenness of technical and technological advances, the pressures of population growth, and the new discoveries of science account in part for today's near-revolutionary situation throughout the world. Vast regions are underdeveloped, and their societies operate with resources that are inadequately and, often, inefficiently utilized. Existing conditions, which may be highly unsatisfactory, are in danger of further retrogression, while dramatic improvements in living conditions and in the general economy of the countries are desperately needed.

This essay is concerned with the development of technology in the poor countries of the world; with the role of engineers and engineering and of science and scientists in this development; with the problems of and the demands on scientists and engineers functioning outside their own cultures; and with their successes and failures in various technical aid programs. Particular reference is made to the situation in, and the experience of, India. This is a large subject, much too large for complete treatment in a single essay. Some factors can only be touched upon lightly, and still others barely alluded to.

We live today in a world dominated by technology. Technology, derived from engineering effort, is in turn dependent upon that world pool to which all scientists in both developed and developing countries contribute and of which all are part. Technological growth seems the only way to

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stability and viability for developing countries if they are to compete as equals in the society of nations. Further, economic and social improvement must be made on a time scale that is reasonable by comparison with estimates of the time available to us before the world is placed in jeopardy.

The industrialization of any one of the emerging countries is a complex problem, which includes both the development of indigenous technology and the importation of technology from more developed countries. This process seems to lead inevitably toward social and economic structures similar to those characterizing the West. An important question, which will not be discussed here, is whether this is the only social and economic structure available to man, and whether it should be the pattern followed by countries in Asia, Africa, and Latin America. These countries may not be able to achieve a competitive position in the world markets without losing or giving up some of their characteristic cultures. No one can now say if this is good or bad, or that, given the opportunity, an alternate road to another social and economic structure is available. It is not even certain that, should such a different structure develop, it could coexist with ours.

It is evident that if answers are to be found, such questions demand perceptive analysis and understanding of the history, the sociology, the culture, and the anthropology of the changing country. It is also evident that such factors will vary from country to country and that, quite possibly, the answers will be different for each. This is of interest to the academic world and important to history, but the processes of concern discussed here cannot await complete understanding before a country proceeds surefootedly into the future. Such understanding is not available even to us in the West, and the problems appear to be infinitely more complex in other parts of the world than in ours.

The discussion that follows will deal with much more pragmatic matters – present-day difficulties in the growth of industry and in science, engineering, and technology. It is divided into seven principal sections: the first is concerned with problems of terminology, and the remaining six with technical assistance needs, technological problems, manpower needs, university-industry relationships, and problems of management and law.

To understand science, engineering, and technology, it is first necessary to ask how these are related and to question the functional relationships which exist among scientists, engineers, technicians, and artisans. The definitions are not important from the standpoint of semantics, but rather because the meanings of words structure our thinking, and this, in turn, influences our efforts.

The difference between science and engineering is real and easily identified. Wilstätter, a German biophysical chemist of the turn of the century, is credited with saying of himself and of his fellow scientists that "our mission is to unveil, not to create."[1] By whatever name, there seems always to have been an activity of man devoted to the search for and the accumulation of data about the world in which he lives, to an understanding of its functioning, and to the statics and dynamics of its responses. This we have always called science. Engineering, on the other hand, is concerned with the use of knowledge, with the utilization of this product of science to guide and to change the operation of the world. The mission of engineering is to create, to bring about new products, systems, and structures as required by man for the continuing growth and continued functioning of his social system. It is important to note, however, that this difference is not necessarily one that permits classification of people. It is one that permits classification of function and certainly of motivation, of objectives, and, hence, of optimum paths to success.

Engineering as a profession has always existed as a force for change in society. It started with the beginning of man's recorded history; it developed through military engineering for the world's armies during the alchemical days of the Middle Ages; it grew with the Industrial Revolution and the growing West of the nineteenth century. Only in the twentieth century has engineering realized equal status with science on the university campus and in society. Until recently, it was commonly accepted that missiles which took off without difficulty from Cape Kennedy were scientific triumphs, while those which had difficulty at the launching pad were engineering failures. This, happily, has changed. Recently, but importantly, the public has become ready to accept the idea that science contributes knowledge, tools, and information and that the engineer uses them all to accomplish a mission. The two are linked, the second feeding on the first.

Technology is yet another matter. This is a body of knowledge, a know-how, a collection of techniques relating to some specific process, operation, or activity. It is not the activity itself. A technology is the result of an engineering development usually fed from the results of many sciences and many scientific studies. Thus, we have a sulfuric acid technology, a technology relating to space flight, a pharmaceutical technology for the manufacture of specific drugs, a technology for molding plastic bottles, and, indeed, a technology for open-heart surgery.

The words "research and development" are properly juxtaposed as are "science and engineering," but the word "technology" is not properly paired with either. Research and development, then, yield technologies, which, linked through national and international markets, provide the economic base for a nation's growth. Engineering provides the link between scientific knowledge and its use by society.

[1] Wilstätter, Richard. From My Life: The Memoirs of Richard Wilstätter (Lilli S. Hornig, translator, and Arthur Stoll, editor, New York, W. A. Benjamin, 1965).

Before leaving this subject, it seems wise to discuss briefly the terms "applied science" and "engineering science." These are familiar terms, usually undefined, which often mean something different to each person using them. The engineering sciences seem to have become those fields the scientists have abandoned in an incomplete state of development, together with those that underlie all engineering specialties. The latter include, for example, fluid mechanics, rheology, and electronics, all of which were once recognized areas of specialization for physicists, who laid their foundations. Today, such subjects are most frequently found in schools of engineering.

Applied science is an even more baffling term, because history teaches that all science – or, rather, all results from science – are eventually applied to the solution, clarification, or redefinition of some problem of the world. Hence, all science is or should eventually be applied for some purpose of man. It seems reasonable to suggest that these terms should not be used until their definitions are clear and their understanding more universal.

Turning next to technical assistance, the need for Western aid throughout the developing countries seems obvious. The food shortage in India has been detailed exhaustively in the popular and technical press – for example, in the 1966 Year Book of *Chemical and Engineering News*.[2] Problems of internal transportation intensify the situation by slowing distribution from the production centers and the sea ports into the populous interior. On the surface, the import/export ratio appears to be improving steadily (see Table I), but exports are largely those items other nations consider noncritical, while imports are those vitally needed to maintain both a people and a slowly growing economy.

Major industries have continued to grow, as is indicated in Table II, but have been hampered by insufficient foreign exchange and by an inadequate manpower pool. They have also been faced with increasing demands from a population that is now responding to the coercive power of technology and that believes only industrialization can yield economic viability, a fully competitive position on world markets, and a standard of living which the people have now discovered possible and, in consequence, want. The needs of India exemplify, and to some extent typify, those of other poor countries, for some of which the term "developing" is still an expression of optimism.

The central goal of assistance efforts is the further development of the technological base from which poverty can yield to some measure of affluence. This cannot be done without some thought to the time available. Population growth – both in a specific country for which we feel a national concern and in her neighbors – creates a demand for action on a time scale that is smaller than the interval during which the problem can possi-

[2] Far Eastern Economic Review (1966 Year Book), pp. 170, 174.

TABLE I

Indian Imports by Commodity

	(*Rs million*)	
	1964	*1963*
Agricultural products	3,320	2,660
Processed natural products (e.g., rubber, fertilizers)	1,290	1,440
Manufactured products	5,540	5,280
Metals	1,530	1,370
Others	820	1,030
TOTAL	12,500	11,780

Indian Exports by Commodity

	(*Rs million*)	
	1964	*1963*
Agricultural products	2,356.9	2,388.9
Processed natural products (e.g., rubber, fertilizers)	1,226.7	1,146.3
Manufactured products	2,297.9	1,932.4
Metals	none	none
Others	2,468.5	2,362.4
TOTAL	8,350.0	7,830.0

From: Far Eastern Economic Review, *Chemical and Engineering News* (1966 Year Book, Washington, American Chemical Society).

bly be solved. As a result, this world demand cannot be approached in a leisurely manner, and it is impossible to hope that science may find a new solution – a "breakthrough" – which will obviate the need for existing technology. We must make use of what is now available, of the reserve of technology derived from the world pool of science, and we must aid by guiding the establishment of appropriate, as well as possible, technologies from that reserve to meet the need head-on.

Ten years ago a new product of the pharmaceutical industry cost ap-

TABLE II

Production In Selected Industries

	1961	1962	(4 months) 1963	1964	1965
General Index (1956 = 100)	139.2	151.3	163.8	174.7	184.7
Coal, 10^6 metric tons	56.1	61.6	66.9	64.0	23.0
Steel, 10^3 metric tons	4,027.0	5,090.0	5,971.0	6,032.0	2,086.0
Cloth, 10^6 meters	4,694.0	4,480.0	4,423.0	4,654.0	1,555.0
Cement, 10^3 metric tons	8,245.0	8,587.0	9,355.0	9,690.0	3,397.0
Jute, 10^3 metric tons	971.0	1,183.0	1,236.0	1,272.0	448.0
Petroleum products 10^3 metric tons	6,090.0	6,584.0	7,650.0	8,450.0	2,741.0
Chemical industries					
(salt, caustic soda, soda ash, chlorine, bleach, bichromates, sulfuric acid, superphosphates) 10^9 metric tons	819	936	1,142	1,329	463
Nonferrous metals					
(aluminum, antimony, copper, lead) metric tons	31,388	48,695	67,425	68,942	22,664

From: Far Eastern Economic Review, *Chemical and Engineering News* (1966 Year Book, Washington, American Chemical Society).

proximately $1,000,000 in research expense. Today a new drug costs more nearly $4,500,000. Industry today plans on a five-year period for new construction to be paid off and a seven-year period for new research. Such considerations lead to only one conclusion—that the cost of research leading to new products is enormous and must today be the business of the developed countries of the world. The underdeveloped countries cannot afford it as a basis for national growth, but should be aided toward their growth objectives through the transfer of technology.

The development of new industry to make use of a known technology in a new form presents an array of problems resulting from the existing culture and the total economy of the country; it also devolves on the entire socioeconomic system. Some items of particular importance are discussed briefly in the following paragraphs.

The actual process of developing a new industry is of an almost purely technological or technical nature. Some of these are:

1) a market, a known and demonstrable specific need;
2) a known reserve of available raw material in suitable quantity;
3) assurance of electrical power at suitable levels and with satisfactory guarantees of reliability;
4) an appropriate technology with which to proceed, together with some assurance of potentials for new developments with which to remain abreast of competition;
5) an assured manpower pool and reserve;
6) appropriate financing;
7) a favorable technical climate in which the new company may grow.

Almost without exception, these factors affect the development of a new industry or the location of a new factory or plant, whether in the United States or in one of the developing nations. The need for financial backing of new ventures is, of course, the *sine qua non*. In the poor countries of the world this must almost by definition come from a government source and points up the need for a three-way interaction among government, industry, and the universities. This has been so basic to developments within the United States during the past three decades that it is sometimes overlooked as obvious. It is far from obvious. Rather, it is often a very weak link in the chain.

Similarly, the need for a market – the need for a need, so to speak – seems obvious, but is not. Marketing a product within a nation composed of villages is quite different from marketing in a commercially-oriented society. It is not even clear that what is most badly needed can be sold – or given away. It is, again, not my purpose here to go beyond making note of such problems. To say more would need detailed analysis.

It is not sufficient that raw material required for the proposed plant be available locally. A supply must be assured for the life of the plant. In addition, in the developing countries one must consider the availability of the supporting raw materials, not just that specific material to be used in the processing operation. Transport of materials to and from the plant site can be a critical factor.

The shortage of electrical power is another factor that often impedes the process of industrialization. A satisfactory level of power availability is not enough for new plant development. The reliability of the power supply must also be guaranteed.

The technical climates provided by the local and national governments are both important. For example, the government of India has not always made it easy for either foreign or indigenous entrepreneurs. Policies have been confusing to both. The paper work attendant upon new enterprise in the United States is fierce; in India it almost seems designed to be prohibitively complex. Concern over foreign currency, the need for a variety of government sanctions, the diffuseness of the administrative machinery, and the inability to get the required decision and approval at the right time may dampen enthusiasm before discussion of an enterprise is well started. Foreign investors have often felt the game is not worth the candle. Indigenous investors, too, are not encouraged. Planning a new industry is critical and troublesome. In a poor country, it is necessary to allocate limited resources wisely among many possible projects. This must be done with great care and decisiveness if there is to be reasonable progress.

Let us now consider the manpower needs so vital to industrialization. The supply of engineers in India is inadequate both to expand present industry and to start new industrial development. In the United States, with about 190,000,000 people, our census lists approximately 1,300,000 persons functioning in engineering capacities; approximately 800,000 of these have been graduated from engineering colleges, schools, or accredited institutes. At the present time, approximately 35,000 bachelors in engineering are graduated each year. In India, a country of almost two and one-half times our population, the engineering manpower pool is an order of magnitude smaller, and the production of engineering bachelor's degree graduates in 1965 was approximately 13,000.[3] Although the figure of 13,000 represents an impressive stride forward since Independence, it is nonetheless inadequate for the development required.

Consider, moreover, the quality of Indian graduates. About fifty universities and institutes in India offer engineering degrees. Graduates from only a handful of these can qualify academically for admission to graduate study in the United States on an equal basis with graduates from, say, our better state universities. A more optimistic view is provided by India's relatively new institutes of technology. Their engineering graduates are being successfully admitted into graduate work in engineering schools throughout the United States on the same bases as those used for American graduates.

The problems of education in India are well known, and those of engineering education are great. Poorly equipped laboratories and libraries, poorly equipped instructors, emphasis on rote learning, the system of examinations being given by people outside the institution, and a hierarchical control by an "old guard" have all been discussed at great length. It is encouraging that the institutes of technology and some few but important

[3] Sundaran, K. N. "Engineering Manpower—A Study of Our Resources and Requirements," *Manpower Journal* (New Delhi), 1965, Vol. 1, Nos. 3 and 4. (This is the first report of the Engineering Manpower Survey made by the Institute of Applied Manpower Research, New Delhi.)

universities have shown the way to new excellence in engineering education.

Consider also the need for technicians and artisans, including glass blowers, welders, mechanics, machinists, plumbers, and other semiskilled, subprofessional labor. It is impossible even to estimate the shortages, but they are critical in all the developing nations. However, here again there are bright spots. For example, the polytechnics (polytechnical schools) of India are a step toward a source of such men and women for the nation.

Of all types of manpower, the one most conspicuous by its rarity is the initiator, the entrepreneur. Many detailed decisions, made with proper timing, are requisites in planning for the development of any industry. In the United States, it is often said that if we wait to build a new plant until we know how, we have waited too long. A spirit of entrepreneurship, of confidence in the future, of confidence in the country, of a willingness to take a chance, to gamble, are vital factors. They are not common within the industrial community of India.

I have not yet discussed the need for new science and for an increase in the number of scientists in India to accomplish their industrialization goals. This was not an oversight on my part. Whenever a new plant or industry development is considered, appropriate technology is an indispensable adjunct. But today, technology for most industrial ventures of interest to India is available on the world market, in the texts, and from that international ocean of published science of which Indian scientists are so clearly a part and to which they contribute. India *is* developing her scientific manpower, and from that will come new technology; men are needed now who can use what is available. The process of industrialization can best proceed by the transfer of technology from the world supply to the Indian scene, not through new science.

One reason for the frequent turn toward science as the source of needed change in developing societies is the simplicity with which one may implement assistance to this activity. Given the funds, a basic research laboratory is easily established, outfitted, and manned with little regard for the encompassing society. The products from such a laboratory – research papers for the prestigious scientific journals of the world – are easily counted and judged, but they do not meet the economic needs of less-developed countries.

Industry-university relationships are also a vital part of industrialization processes. There is a long history of dialogue between universities and industries in the United States. Engineering faculties, both junior and senior, act as consultants for industry and work in industrial design and development laboratories during the summer months. This is an accepted part of the total picture, and a department head or dean would look carefully at any member of an engineering faculty who isolated himself from an industrial experience. In turn, industrial people are associated with the engineering schools as colleagues. They actively recruit young men on the campuses, visit with faculties, participate in seminars, and enjoy warm personal contacts. A dialogue of criticism, an exchange of problems, and a careful examination of techniques used in both the academic and the industrial approach characterize the world of engineering and engineering education in the United States.

Generally, none of this is true in the developing countries, and certainly not in India, although a start has been made. To develop an industrial nation, this type of constant exchange, of mutual support and reinforcement, and of criticism, must develop between the engineering faculties and the industrial leadership of the country. This will not grow out of contact with the American, English, German, or Russian personnel in the foreign-dominated industries. It must develop between local industrial leaders and the local university faculty.

Management is another significant aspect of industrialization. A new development or a new technology in any country must be guided through its initial phase to a condition of viability as part of the existing socio-economic system. Success in this phase of the endeavor will depend upon good management. Almost more than any other part of economic development via technological growth, management must base its operational approach on the culture within which it is born. Western management concepts are not necessarily the best for countries that are developing. Indeed, it is a most unlikely situation. Western management experts have difficulty in applying their know-how in countries whose cultural base is totally different from theirs. As management continues to develop in the West, "principles" held to be true for Western culture may not only prove invalid within that culture but will almost certainly be questionable in another.

Good management must be able to empathize in some degree with the attitudes and prejudices of those who are being managed. Without that empathy, grave difficulties are likely to ensue when these attitudes and prejudices, rooted as they are in a culture, are grossly different from those of the manager. Many elements of culture affect management. These include the concepts of success and failure, achievement, accomplishment, the interrelationship of elements of the society, the attitude toward entrepreneurship, and the attitude toward time. Of these, the concepts of achievement, of the structure of the society, and of time are the most critical.

The language problem is one of the most subtle in the process of industrialization. It is important that the language be suitable to the process, and the need for language structures thinking. For example, Tamil, the language of South India, is not one in which the subtleties of chemical transformations or, for that matter, vital interpersonal relationships, can be expressed precisely.

Finally, let us turn to law. The beginning of a new venture that follows introduction of new technology (new in either the absolute or the relative sense) automatically involves not only such considerations as management, markets, and manpower, but also the legal structure of the country. All countries, developed and developing, have a body of law governing interpersonal relationships between individuals, groups of individuals, and organizations. In many cases, this body of law is not adequate for modern purposes.

Law systems are different, of course, in each country. United States law is often called "common law," "case law," and sometimes "Anglo-American law." The other extreme, found in Mexico, France, and some other countries of the world, is called "legislated," "code law," "Roman law," or "civil law." None of these adequately describes the systems, and the differences are sometimes more of degree than of kind. The first is a creation of the English Parliament with influences from Roman law; the second is a direct continuation of Roman law with the addition of other influences. Details are much beyond the scope of this essay.

The legal structure of India differs from that of the United States or Britain in many important ways. Those differences are important, relating as they do to the extent to which bearer shares are accepted as part of the juridical doctrine, the existence of unissued stocks in corporations, the power of the board of directors relative to that of the stockholders at stockholders' meetings, the extent and kinds of liabilities, and the extent and degree of government and public control of corporate functions. I mention this only to stress that the transfer of technology from one nation to another, and the development therefrom of an industry as part of a growing and viable economy, depends on much more than engineering competence.

There are, thus, many problems attendant upon the industrialization of all developing countries. Personnel to guide development; appropriate technology and related needs; management; and the legal and administrative structures of the country are but a few. The need for and the encouragement of the entrepreneur; the development of supporting labor; the entire educational system and, in particular, the engineering programs throughout universities; communications between industrial engineering leadership and the university faculties must all be considered during any project. In India, all these must also be considered against the backdrop of a five-thousand-year-old culture that is structurally and philosophically different from ours. In this surely pessimistic picture, what of the future?

Given limited resources for a large and long-range objective, it is critical that careful allocations be made among the various important needs. Those activities that are considered most prestigious in world terms are not necessarily those that can or should be given prime attention. Industrialization through appropriate existing technologies, used in their proper context with consideration for the economy and total structure of the pertinent country, seems the only clear path to reasonable equality of opportunity and comfort for all people of the world within a reasonable time. Progress is being made.

Scientific Education and Research in Pakistan

M. RAZIUDDIN SIDDIQI

IT IS GENERALLY RECOGNIZED that after Pakistan achieved Independence, people in many walks of life had to start almost from scratch. This is particularly true of higher education in science and scientific research. This essay gives a brief account of the new organization and developments in these two areas. We shall be concerned mainly with four types of institutions: universities and colleges; scientific departments of the central and provincial governments; autonomous or semiautonomous councils and institutes of scientific research established by the government; and the learned societies, associations, and academies established by the various groups of scholars in the different branches of science.

The development of scientific education and research in the modern sense is of comparatively recent origin in the regions now comprising the land of Pakistan. In 1947, before Independence, there was only Panjab University in the West and Dacca University in the East. It is obvious that these two institutions were wholly inadequate for a population of almost a hundred million people.

Panjab University was established in 1882, and was for a long time an affiliating and examining body; most of the teaching work was done in affiliated colleges scattered over the whole province of the old Panjab and administered and maintained either by the provincial government or by private philanthropic societies. The academic control of these colleges was vested in the university, which prescribed the courses and syllabi, conducted the examinations, and conferred the degrees.

This system of remote control, which is technically known as affiliation, is perhaps unique to this region, and is generally considered to be respon-

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sible for many of the defects in the present educational system. Among affiliated colleges, few taught the basic sciences up to the degree level. The Government College, Islamia College, and Forman Christian College at Lahore, the Islamia College at Peshawar, and Gordon College at Rawalpindi were perhaps the only institutions that had any reputation for such science teaching.

Postgraduate studies in science were started later, and were originally confined to one or two colleges, notably the Government College, Lahore. Later, the University established a Department of Mathematics and an Institute of Chemistry under its direct control. The University Institute of Chemistry and the science departments of the Government College had acquired some reputation for advanced work in the various sciences.

In the southern region of West Pakistan, comprising the old province of Sind and the then state of Khairpur, the picture was even more gloomy. The educational institutions of this region were affiliated with the University of Bombay. But there were hardly half-a-dozen degree colleges in the whole area, and the D. J. (Diamond Jubilee) Science College at Karachi was the only noteworthy institution that imparted instruction in the basic sciences on the undergraduate level. Postgraduate work was negligible. Anyone who wanted to pursue a course of advanced studies had to go to Bombay, Lahore, or Aligarh, or to other universities within the subcontinent or in foreign countries.

Turning to East Pakistan, we find that Dacca University, which was established in 1921 as a unitary teaching institution, had developed some good science departments, especially in physics and chemistry, the reputation of which had spread beyond national frontiers. Apart from this, there was virtually no other science college worth the name in the whole eastern part of what was then Bengal.

This was the inconsiderable legacy inherited by the new nation. Making matters worse was the confusion created by the unprecedented influx of hundreds of thousands of students who migrated from across the border and who naturally wanted to be taken into the few existing institutions. The resources in personnel, equipment, and laboratory space, already too meager, proved totally inadequate for the extraordinary rush, which had swollen beyond all reasonable limits.

The heroic efforts of the people and the authorities saved the situation and kept the educational life in the country going. The acute shortage of qualified and experienced teachers and the lack of adequate equipment and other facilities had a disastrous effect on academic standards; but the few selfless and devoted teachers and administrators who were available at the time were able to avert the impending catastrophe and restore a semblance of order to the prevailing chaos.

It was essential to give this brief resumé of conditions at the time of Independence, because the present status of education in Pakistan, and the efforts made during the last few years, can only be understood when this background is kept in view. At present, there are ten universities and 360 colleges in the country. Of these, there are two universities of engineering and technology and two of agriculture. There are 63 professional colleges. The total number of students in the universities is about 20,000 and in the colleges about 250,000. The government has decided to set up three new universities immediately. A number of additional colleges of agriculture, engineering, and medicine are also being established.

All the universities have honors and postgraduate teaching in the basic sciences, in addition to the humanities and the social sciences. Excepting Lahore, where some of the older colleges have a tradition of postgraduate teaching in some subjects, all honors and postgraduate studies are confined to the university teaching departments. This is mainly because teaching at this level needs a team of highly qualified and experienced teachers, and since the number of such persons is limited at present, it has been considered desirable to concentrate resources in one center in each area – the university – and bring all advanced students to this center. This restriction is, however, being lifted gradually, and the colleges are being allowed to start honors and even master's-degree work when they have the necessary resources in men and materials.

Immediately after Independence, the policy was adopted of sending promising young scholars abroad for advanced studies and training. This is bearing fruit, and the university departments and colleges are being manned increasingly by these highly qualified teachers. The policy is being pursued with greater vigor now, and a large number of young teachers and scholars are being sent abroad every year.

These programs of training are being arranged under two main categories – Pakistan's own programs and foreign aid programs. In the first category are the scholarships and study-leaves on full or half pay granted by the central and provincial governments and the universities and colleges, as well as the private arrangements made by scholars who are allowed foreign exchange by the authorities. In the second category are:

1) technical assistance programs of international organizations like UNESCO, IAEA, etc;
2) project-linked training programs of the UN Special Fund, etc;
3) training facilities offered by the Commonwealth countries under the Colombo Plan and under the Commonwealth Scholarship Scheme;
4) scholarships and fellowships offered by foreign governments under bilateral pacts of cultural cooperation.

Panjab University in Lahore has developed departments of mathematics, statistics, astronomy, physics, pure chemistry, technical chemistry, botany, zoology, geology, geophysics, geography, and sociology. Naturally, some of these departments are more developed than others, and Lahore, which had been a great center of education before Independence, has now become an important seat of learning to which students are flocking from all parts of the country. In Lahore, apart from the university departments, are the Government College, Islamia College, and the Forman Christian College, which participate in postgraduate teaching. In addition, there are degree colleges in almost all district headquarters and in other big towns; they give instruction in science up to the B.SC. level and, in some cases, to the honors and M.SC. level as well.

The University of Dacca is another important center of scientific education and research and has almost overcome the setback it suffered at the time of Partition. It has departments of mathematics, statistics, physics, chemistry, biochemistry, soil sciences, botany, zoology, geology, and geography. Some of these departments are active in research, besides producing a large number of postgraduate students. All the efforts of the authorities and students were concentrated for a long time on this single university in the whole province of East Pakistan, so it has benefited greatly and developed rapidly. Many of its science departments have a large number of foreign-trained staff members with high research qualifications and experience.

Sind, established in 1947, is the oldest among the new universities, but did not create teaching departments in the sciences until 1955. It maintains departments of mathematics, statistics, physics, chemistry, botany, zoology, geology, and geography. As it was functioning in an old school building, it was extremely cramped for space and also suffered from a shortage of staff and equipment. Recently, the science departments have been shifted to a new campus outside the city, and more qualified and experienced staff members have been appointed. The number of students has increased considerably, and the university is trying to develop into a residential teaching institution – which is relatively rare in Pakistan.

Peshawar University, established in 1950, has generous resources placed at its disposal by the government. From the very beginning it has emphasized the development of scientific and technical education, not only in the university but also in the affiliated colleges scattered throughout the province. The university has established departments of mathematics, physics, chemistry, botany, zoology, geology, and geography, and the presence of faculties of engineering, medicine, and agriculture under the unified control of the university has given considerable impetus to the development of the basic science departments. Because it has adequate residential accommodations and other facilities, as well as beautiful, historic surroundings and a salubrious climate, teachers and students from other parts of the country are keen to take advantage of the opportunities available there. The university bids fair to become a great center of learning for the whole region.

The University of Karachi, which was founded in 1951, has attracted talent from all over the subcontinent. It is financed and patronized by the central government and is located in the largest city of the country, which was the capital of the government until a short while ago and which is still the greatest center of commerce and trade. Under these conditions, the university was able to acquire the services of foreign professors, pay teachers higher salaries, and purchase necessary apparatus and equipment. It maintains departments of mathematics, physics, chemistry, botany, zoology, microbiology, geography, and geology. The new buildings constructed on the campus outside the city are now occupied, and the university has a good opportunity of developing a proper academic atmosphere.

The youngest institution of a general type in Pakistan is Rajshahi University, situated in the northern district of East Pakistan. It was established in 1953 and is gradually developing into a teaching and residential university. It has departments of mathematics, physics, chemistry, botany, and zoology.

So far, I have confined my account to a description of the organization of science teaching in the universities. As already stated, honors and postgraduate teaching—except for the City of Lahore—is confined to these universities. But the expansion of education since Independence has seen the establishment of a degree college in almost every district of the country, and many of them include basic sciences in their curricula.

Whereas at one time students had to be persuaded to take up science, the authorities are now, in many cases, compelled to restrict admission to these courses because of shortages of staff, equipment, and space. The pressure for admission to the science classes is so great that more and more intermediate colleges are being raised to the degree level each year, with arrangements for teaching the basic sciences.

The situation with regard to technical and professional subjects—engineering, medicine, and agriculture—is still more acute. Although the number of colleges in these specialties has increased several-fold since Independence, there are as many as five to ten applicants for each student vacancy. Consequently, the authorities must resort to selective admission through a competitive examination or on merit in the entrance examination. To develop advanced studies in the professional subjects, the Commission on National Education (1958–59) had recommended the establishment of agricultural and engineering universities in both wings of the country. In 1961, the government opened four such universities.

This is just a bare enumeration of the facts and figures regarding the development of scientific education in Pakistan. The authorities have not neglected the inner content and standards of this education. The courses, the syllabi, the teaching methods, and the system of examination have all been subjected to a thorough scrutiny during the last few years, and ideas have been crystallized and given concrete shape by the Commission on National Education. Many reforms have been introduced since the academic year 1960–61; they are slowly but surely having a profound influence on the development of scientific education and research in Pakistan.

Because research to advance knowledge is regarded as one of the main functions of a university, Pakistani universities are now attaching great importance to it. The reorganization of the whole educational system in the light of the recommendations of the Commission has done a good deal to improve the standards of teaching and research. An honors degree course, as distinct from a pass course, has been introduced to give more scope to the brilliant student who wishes to specialize and proceed toward advanced studies. The teachers, especially those in the senior cadres, have been told that their promotions and even their continuation in the university department will depend upon research work of approved standards. Libraries, laboratories, and other facilities, such as opportunities to attend scientific conferences and to visit other centers of research in foreign countries, are being provided in ever-increasing measure. Each Pakistani university has some schools of research developing around the competent and active individuals it has managed to attract.

Two more steps have been taken recently. It has been felt for some time that postgraduate studies and research have not been developing in the universities as satisfactorily as they should, and it has been generally recognized that without such development, the over-all progress of the country in the educational field, as well as in other walks of national life, will be seriously hampered. The country needs a large number of experts and specialists in various branches of knowledge for the purpose of meeting the requirements of our colleges, universities, research councils, scientific departments of the central and provincial governments, and the continually expanding sphere of trade and industry. National plans for economic development depend on the production of a large number of men of requisite competence. The Third Five-Year Plan, involving a sum of Rs 52,000 billion (about $11 billion), aimed at a definite breakthrough in education to provide the manpower requirements of an industrialized society in an era of science and technology.

So far, the country has had to depend largely, if not wholly, on sending its scholars abroad for higher training. The numbers have, however, reached such dimensions that it is no longer feasible to depend solely on the program of overseas training. Adequate arrangements must be made within the country itself. For instance, in mathematics or physics there are a number of major branches for teaching and guiding research. In each of these, separate specialists are needed at the postgraduate level. Postgraduate studies in the country have not prospered so far, mainly because none of the universities has the requisite number of competent staff in any one subject. As a matter of fact, there is not a sufficient number of such people in the country to meet the requirements of all the universities. The few good people in any one subject are scattered all through Pakistan.

To rectify this deficiency, the authorities have decided to develop centers of advanced studies in one or two scientific subjects in each university, so that it can concentrate its efforts on bringing the centers up to an international level. This development has just started, and it is hoped that during the Third Plan period each science subject will have a well-developed center of advanced study and research in at least one university in the country.

The central government has also decided to establish a postgraduate university at Islamabad, the national capital. This will concentrate on advanced studies and research and produce highly qualified teachers and research scholars for other organizations. A suitably qualified staff is now being assembled for this university, and it will concentrate on postgraduate studies in the basic sciences for the next few years.

Turning now to other scientific organizations, we find that a number have been started during the last thirteen years. Among them may be mentioned first the scientific departments set up by the central and provincial governments. Some of the important ones are:

1) Survey of Pakistan
2) Geological Survey of Pakistan
3) Meteorological Department
4) Plant Protection Department
5) Fisheries Department
6) Department of Agriculture
7) Department of Animal Husbandry and Veterinary Sciences
8) Department of Medicine and Health
9) Department of Works and Irrigation

Many of these had to be newly started in Pakistan after Independence. Even so, they have assumed respectable dimensions now, and are contributing substantially to the development of their respective fields. They are attached to departments of the various ministries in the central government and to secretariats in the provincial governments. In many cases, they are the largest employers of scientists produced by the universities and, in this respect, are also helping the development of science in the country as a whole. The professional colleges of agriculture, medicine, and engineering are generally administered by these departments, although the government has recently decided to develop them into full-fledged universities or make them into autonomous research-guiding institutions.

The government has also established some laboratories and research institutes, such as the Bureau of Laboratories at Karachi, the Geophysics Institute at Quetta, the Irrigation and Hydraulics Research Institute at Lahore, the Forest Research Institute at Abbottabad, the Malaria Institute at Dacca, the Cancer Institute at Karachi, and the Defence Science Laboratories at Rawalpindi. The scientific departments have a number of research and experiment stations scattered throughout the country. These are contributing in no small measure to the agricultural, economic, and industrial progress of the country.

A significant development in the scientific field has been the establishment of autonomous or semiautonomous research councils and committees. The first, in 1949, was the Agriculture Research Council. The Ministry of Agriculture also set up the Cotton Committee and the Jute Committee to give impetus to improvement in these most important cash crops. These committees have established research institutes in Karachi and Dacca respectively.

But the research organization that has developed more than any other is the Pakistan Council of Scientific and Industrial Research (CSIR), started in 1953. The CSIR has multisubject laboratories in Karachi, Dacca, Lahore, and Peshawar. These are actively engaged in applied and developmental research useful for industrial applications. A number of industrial processes have been completed and have been given over to manufacturers for exploitation. Other laboratories are being developed at Chittagong, Rajshahi, Quetta, and Islamabad.

The Ministry of Industries set up an Atomic Energy Committee in 1955 and developed it into a Commission in 1956. The Commission sent a number of Pakistani scientists to Britain, the United States, and other countries for advanced training in the various nuclear sciences and technologies. It also set up training and research centers in Lahore and at Dacca. The Central Institute of Nuclear Science and Technology was organized at Islamabad, and a swimming-pool type of reactor was installed there. The Commission also established a radioisotope medical center at the Jinnah Hospital in Karachi, where nuclear radiations are being used for diagnostic and therapeutic purposes. Similar medical centers have been set up at Lahore, Dacca, Multan, and Hyderabad. Nuclear centers for agricultural research are also under way – one such is already operating at Tandojam – and others are being set up at Lyallpur and Mymensingh.

The Medical Research Council, under the aegis of the Health Ministry, has also been in existence since 1951. It has been recently reorganized and strengthened and is devoting a good deal of attention to promoting research in the various branches of public health and medicine.

Two other research councils – one on housing and works, the other on irrigation and flood control – were established recently and are developing their scientific and research programs. Plans have been made for the development, under these research councils, of institutes for research on arid zones, humid tropical deltas, and waterlogging and salinization.

All these research councils are autonomous. They are, however, attached to the corresponding ministries of the central government for policy control and budgetary support. In 1959, the government of Pakistan, which supplies the funds for virtually all scientific research, appointed a high-level commission to consider and report on the ways and means of promoting scientific research, of assuring the utilization of results of research for the over-all development of the country, and of making scientific careers attractive to talented scientists. The commission submitted its report in 1960.

One of its major recommendations was that a central organization, called the National Scientific Council, should be established to coordinate the work of the research groups, assess and evaluate the results of research, recommend measures for using them, and generally advise the government on all matters connected with the development of scientific activities. It was established in 1962, and is comprised of the heads of various research councils, representatives of various universities and scientific departments of government, and some eminent scientists nominated by the President.

About a year ago the government went one step further and created a ministerial Division for Scientific and Technological Research in the President's Secretariat. This division deals directly with the Council of Scientific and Industrial Research, the Atomic Energy Commission, the National Science Council, and indirectly with all other central or provincial research organizations. Its functions are to promote scientific and technological research in all possible ways, to collect and disseminate information about the latest scientific developments within the country and abroad, and to arrange for using results of research for the economic development of the country. Initial work in the establishment of this division has been completed, and it is now capable of carrying out its responsibilities.

Finally, we come to the learned societies, which are universally recognized as constituting an important means of promoting higher studies and research. As in other aspects of scientific endeavor, Pakistan had to initiate these societies and scientific associations. The first important organization to be established was the Pakistan Association for the Advancement of Science, which was set up on the lines of the British Association for the Advancement of Science. The latter has served as the prototype for such organizations in the Commonwealth and other countries. The Pakistan

Association held its first annual conference at Lahore in 1949, and since then has held such conferences every year at various centers throughout the country. The association is playing an important role in popularizing science among the people and in making the authorities realize the value of scientific education and research for the progress and development of the country.

Every advanced nation has a high-level organization of scientists whose membership is a recognition of the scientist's outstanding contribution to the advancement of knowledge and his eminence in his particular field. The Royal Society in London, the Académie des Sciences in Paris, the National Academy of Sciences in Washington, and the Soviet Academy of Sciences in Moscow illustrate this point. Some Pakistani scientists who belonged to the National Institute of Sciences of India and the National Academy of Sciences before Partition felt that an academy should also be established in Pakistan. Consequently, with the approval of the authorities, the Pakistan Academy of Sciences was formed in 1953 and has been recognized by government. It has a very limited membership, and only outstanding scientists who have made original and substantial contributions to research are elected as fellows. The Academy is supported and given an annual grant by the Ministry of Education. It advises the government on various national and international scientific matters and has liaison with other scientific organizations at home and abroad.

National societies for the various disciplines have also sprung up during the last few years and are developing gradually into promising instruments for the advancement of the different branches of science. Among these are the Medical Association, the Engineering Association, the Chemical Society, the Statistics Association, the Mathematical Society, and the Geographical Society, as well as others, each organized on an all-Pakistan basis. There are, of course, individual scientific societies in each university and in some of the larger colleges. They cater mainly to the teachers and students of their respective institutions. The Scientific Society of Karachi and the Urdu Academy of Lahore are unusual in that they aim at the development of science through the medium of the Urdu language.

Before concluding, reference should be made to the Pakistan National Science Documentation Centre (PANSDOC), which was established in 1956 by the government of Pakistan with the technical assistance of UNESCO. This center is working under the Pakistan Council of Scientific and Industrial Research and has become an important and valuable source of information and reference for scientific workers all over the country. It provides copies, microfilms, and translations of research papers from various journals and periodicals.

This essay has provided only a brief historical account of the organization and development of scientific training and research in Pakistan. No attempt has been made here to describe the actual contents of academic programs, nor has it been possible to indicate even briefly the topics on which research is being conducted in the universities and the research laboratories. These require separate treatment by individual scientists working in those institutions and agencies.

Advanced Scientific Research in Developing Countries

ABDUS SALAM

FIVE HUNDRED YEARS AGO – around A.D. 1470 – Saif-ud-din Salman, a young astronomer from Kandhar working at the celebrated observatory of Ulugh Beg at Samarkand, wrote an anguished letter to his father. In words more eloquent than I could employ, Salman recounted the dilemmas, the heartbreaks, 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 is not that I covet the musk-melons and the grapes and the pomegranates of Samarkand; it is not the shades of the orchards on the banks of Zar-Afsham that keep 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 times. For Samarkand of 1470, read Berkeley or Cambridge; for quadrants, read high-energy accelerators; for Kandhar, read Delhi or Lahore, and we get the story of advanced scientific research and its dilemmas in the developing world of today as seen by those who feel in themselves that

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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 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, if they could, to foster scientific research, even advanced scientific research. Unfortunately, research is costly. As we have seen, most countries do not yet feel it carries a high priority among competitive 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 from the world market. The final picture, so far as advanced research is concerned, remains almost as bleak as at Kandhar.

Let us examine some of the factors that affect advanced research. To me, the first and foremost determining factor for all advanced research is the supply of towering individuals, tribal leaders, around whom great institutes are built. These are perhaps five per cent of all the men who are trained for research. What are we in the developing world doing consciously to ensure their supply? To my knowledge, most developing countries are doing practically nothing. To me it is astonishing, miraculous, that, considering all the hazards that beset a poor society, any talent at all is saved for science. These hazards are, first, poor schooling; second, the Indian Civil Service and its analogue, the Civil Service of Pakistan, which skim off the very top of the subcontinent's intellect; third, the chancy nature of any opportunities for an extended apprenticeship for research. Add to this the greatest hazard of all: one may or may not be fortunate in getting a position with the few men – in the case of India and Pakistan, the Siddiqis, the Usmanis, the Menons, the Sarabhais, the Seshachars, at the few centers of excellence – who at all appreciate the demands of a research career and who run laboratories that are reasonably well equipped. As Doctors Seshachar and Siddiqi have said, it remains a sad fact that although India and Pakistan may have built specialized institutes outside the university systems where advanced research is carried out, for the most part the university systems remain weak, static, uninspired. I shall always remember my first interview with the head of the leading 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, take up Presidentship of its Football Club.

As it was, I was fortunate to get the Football Club.

Admittedly, this was fifteen years ago. I would be ungrateful if I did not mention that today this same college is contesting with the Atomic Energy Commission of Pakistan for 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, to which Dr. Siddiqi referred. Things have changed, and I would like to illustrate the present position, the immediate needs, with reference to research in an area with which I am familiar – theoretical physics.

My thesis is that, in a number of fields, advanced scientific research in developing countries is reaching, and has reached, a stage of first-rate maturity. The indigenous resources are being skillfully employed, but there still is a desperate need for international help. The truth is that in science, as in other spheres, there are classes of haves and havenots, irrespective of a man's talent; those who enjoy physical facilities for furtherance of their work, and those who do not, depending on which part of the world they live in. That distinction must go. In his Foreword to this volume, Dr. Bronk stresses the importance of meaningful international cooperation in science. I believe the time has come when the international community of scientists should begin to recognize its direct moral responsibility, its direct involvement, its direct participation in advanced science in developing countries, not only in institutional terms but in *personal* terms of the first-rate individual working in these countries.

I would like to illustrate my remarks with reference to theoretical physics. This is one of the few scientific disciplines which, together with mathematics, is ideally suited for build-up in a developing country. The reason is that no costly equipment is involved. Inevitably, it is 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 go to work in advanced centers in the West or the USSR. Then they return to build their own indigenous schools. In the past, when these men went back to their universities, they were perhaps completely alone, there was no critical size of the groups of which they were a part, no good libraries, no communication with groups abroad. They were isolated, and isolation in theoretical physics is death. This was the pattern when I joined Lahore; this is still the pattern in Chile, in Argentina, in Lebanon, in Korea.

In India and Pakistan we have been more fortunate during the last decade. A number of specialized institutes have grown there for advanced work in theoretical physics: the Tata Institute, the Institute of Mathematical Sciences at Madras, Atomic Energy Centres at Lahore and Dacca, where a fair concentration of good men has been made possible. But this is not enough. These institutes still are small islands; they still do not have vigorous contacts with the world community. Tata and Madras have partly solved their difficulties because they have funds to invite visitors; they have fewer funds to send Indian physicists abroad, mainly because of the very real problem of foreign exchange.

It was with this in mind that an International Centre for Theoretical Physics was first discussed in 1960. The idea was to set up a truly international center for advanced research in theoretical physics to be run by the United Nations family of organizations. We planned it with two objectives: first, to bring together physicists from the East and West; second, to provide extremely liberal facilities for senior, active physicists from developing countries.

How does the idea work out in practice? We have normal fellowships that are given primarily to scientists from developing countries. In addition, the International Centre has instituted what we call the Associateship Scheme. A number of leading physicists from developing countries are selected and are given the privilege of coming to the Centre for a period of one to three months every year with no formalities except a letter to the Director. The Centre pays fares and maintenance. Eventually, we should have at any one time a cadre of about 50 senior, active physicists from developing countries. They could choose to come whenever it suits them.

As I look back on my own period of work in Lahore, I remember feeling, as I said, terribly isolated. If at that time someone had said to me: "We shall give you the opportunity to travel every year to an active center in Europe or the United States to work with your peers for three months of your vacation. 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 progress.

We are running the Associateship Scheme at Trieste. Ideally, it should be broad enough to include nearly every active physicist in developing countries. Unfortunately, the International Centre at Trieste does not possess funds to do this, which is why I welcomed so very much the opportunity to plead here for an extension of the scheme.

Briefly, I would like to see large institutions – Princeton, Harvard, The Rockefeller University, the State University of New York, Imperial College, London – consider setting up their own associateship schemes, not only in theoretical physics, but in other subjects, as well. The Rockefeller University, for example, could extend the privilege of giving its freedom not only to Professor Seshachar, but also to other active microbiologists in most developing countries. We have found that the program is not too costly. We pay no salaries – only the fare and a per diem – so, for the 27 Associates we now have, it costs us something like $60,000 each year. Already the European Organization for Nuclear Research at Geneva has started a plan similar to ours, which covers, I believe, both experimental and theoretical physics. Of course, it is designed only for developing countries within Europe. If we could succeed in providing for every active, first-rate worker in such countries throughout the world – perhaps a total corps of about 500 associates, distributed among the rich countries – we would go very far toward removing one of the curses of being a scientist in a developing land.

I have emphasized the personal problem of the advanced research worker. In such research, I believe the personal element counts much more than the institutional. If, through meaningful international action allied with national action, we can build the morale of the active research worker and persuade him to not make himself an exile, we will have won a real battle.

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GOVERNMENT, SCIENCE, AND NATIONAL DEVELOPMENT

Scientific Research in the Developing Nations: Its Role, Organization, and Support

M. G. K. MENON

IN JANUARY 1966, the late Homi Bhabha, first Chairman of India's Atomic Energy Commission and Director of the Tata Institute of Fundamental Research, said in a speech to the General Assembly of the International Council of Scientific Unions in Bombay:

> What the developed countries have and the underdeveloped lack is modern science and an economy based on modern technology. The problem of developing the underdeveloped countries is therefore the problem of establishing modern science in them and transforming their economy to one based on modern science and technology. An important question which we must consider is whether it is possible to transform the economy of a country to one based on modern technology developed elsewhere without at the same time establishing modern science in the country as a live and vital force. If the answer to this important question is in the negative—and I believe our experience will show that it is—then the *problem of establishing science as a live and vital force in society is an inseparable part of the problem of transforming an industrially underdeveloped to a developed country.*[1]

At this point, let us consider the important question Bhabha raised: is it possible to transform the economy of an industrially underdeveloped country to one based on modern technology developed elsewhere without, at the same time, establishing modern science in the country as a live and vital force? Bhabha answered this in an unequivocal manner on the basis

[1] Bhabha, H. J., "Science and the Problems of Development," *Science*, 1966, Vol. 151, pp. 541–548. (Italics are mine.)

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of his extensive experience in India over two decades. A detailed analysis would be very involved, so I will set forth only some general thoughts.

Technology, if by that one means the "knowledge of techniques," has existed for thousands of years and has determined the course of history; our information on this vital subject is fragmentary. Many of the techniques have had a close relation to human life and needs everywhere, so parallel development can be seen to have occurred in many different parts of the world. New capabilities have grown from old ones: the history of technology is full of examples.

However, the present relationship between science and technology is quite different. Today, while distinct in many ways, they move together in a concerted manner. There is little doubt that the educational system plays an important role in linking the two. Modern science is important and necessary for modern technology; the converse is equally true. This delicate interplay – this partnership, as it were – has produced fantastic material progress in the developed nations of the world.

The problem of achieving satisfactory economic growth in a developing nation such as India is greatly intensified by the population explosion. It is a direct result of modern advances in medicine, which have cut down infant mortality, taken long strides in eradicating mass communicable and infectious diseases, and extended life expectancy. Interestingly, rapid accumulation of wealth by the advanced nations came about with the Industrial Revolution and the concomitant expansion of science and technology (which today is growing at 7 per cent a year compounded annually); health considerations came later. On the other hand, in the underdeveloped parts of the world health and social advances have come first, before the wealth needed to sustain them. Having thus made use of the miracles of contemporary medicine and created a population explosion, the only remedy for a nation such as India is to make equal use of other powerful scientific and technological capabilities.

It is relatively simple to list a host of areas – food, communications, electronics, power, geological prospecting, water allocations, and so on – in which recent developments in science and technology should find immediate and vital application. The question might be asked why one cannot simply take these innovations from places where they are readily available; it is obvious that in the world as a whole we do not lack the necessary knowledge.

The problems encountered in such a solution are manifold. First, the world is not as benevolent a place as many of us would like it to be; imported items, techniques, and processes are extremely expensive and often not available under easily acceptable conditions. Second, such a purchase – or gift, as the case may be – does little to encourage a country's self-generating capacity for growth. Third, many local needs are encountered, for which solutions must be found. These – including tropical meteorology to study monsoons, the use of thorium as fuel for atomic power stations, and many others – are of great interest to India, but of much less interest to the advanced nations. Thus, while judicious import of know-how or equipment can act as starting points or nucleating centers, the correct measure for a country such as India, at least for some time to come, is to develop indigenous confidence along broad selected fronts of science and technology.

Concerning this general question C. F. Powell has said:

> In the long run, it is most painful, and very expensive, to have only a derivative culture and not one's own, with all that it implies in independence in thought, self-confidence and technical mastery. If we left the development of science in the world to the free play of economic factors alone, there would inevitably result a most undesirable concentration of science and scientists in too few centres, those rich in science becoming even richer, and those poor, relatively poorer.[2]

In sum, therefore, modern science and technology are clearly interlocked, and it would be difficult to develop one to any extent without developing the other. It is essential to employ many aspects of the most modern technology if any reasonable growth pattern is to be achieved. While, to a great extent, these are available elsewhere in the world, a long-term solution for national development cannot be based completely on importing them. As Bhabha said, "establishing science as a live and vital force in society is an inseparable part of the process of development."

The task of a growing science involves a coordinated effort across a wide spectrum of national endeavor – school and university teaching, new methods of science education, publication of suitable and inexpensive books, popularization of science, training large cadres of technicians, interrelationships among education, research, and industry, and so on. I shall not go into all of these facets here, but will concentrate on analyzing the importance and the role of scientific research in establishing modern science as a live and vital force in society. I will also explore some aspects of the organization and support needed if science is to be a truly effective force for social and economic change. Let me emphasize that, although my experience is restricted to India, much of this discussion applies to many other developing countries.

Budget allocations for science are usually shown under the general heading of "Research and Development" (R and D). Research is further shown as "fundamental" (or "basic") and "applied." Let me define these terms.

[2] Powell, C. F., "The Role of Pure Science in European Civilization," Supplement to CERN *Courier*, 1964, Vol. 4, No. 12.

Fundamental research is concerned with the discovery of new facts and with the understanding of nature. The basic motivation is to know and to understand some hitherto-unknown principle. Questions are asked, objectives are defined, measurements are made, and the methods employed – experimental or theoretical – are the most advanced and sophisticated available. However, these studies are not directed toward the solution of practical problems. Work in pure science is judged by the entire international scientific community. While there are occasional differences of opinion, there is surprising agreement about the merits of any work.

By contrast, there is a definite, practical objective in applied research, which can and should be a highly creative process, involving originality, imagination, and inventiveness. In a desirable situation, these qualities should be of the same magnitude as in pure science; often they are not, for organizational reasons. The degree of creativity should not distinguish pure from applied research, but rather the clear direction of the latter.

Development calls for the effective and economical execution of a task that has been shown to be feasible on the basis of applied research and past experience.

A rough breakdown of the R and D budget in the United States shows expenditures of approximately 15 per cent on basic research, 20 per cent on applied research, and 65 per cent on development. These figures appear to represent balanced growth.

An article in the *Bulletin of Atomic Scientists* entitled "Why Pure Science?" eloquently expounded the importance of fundamental research. It was written by Victor Weisskopf, eminent nuclear physicist and past director-general of CERN, the European center for nuclear research. He said, in part:

The value of fundamental research does not lie only in the ideas it produces. There is more to it. It affects the whole intellectual life of a nation by determining its way of thinking and the standards by which actions and intellectual production are judged. If science is highly regarded and if the importance of being concerned with the most up-to-date problems of fundamental research is recognized, then a spiritual climate is created which influences the other activities. An atmosphere of creativity is established which penetrates every cultural frontier. Applied sciences and technology are forced to adjust themselves to the highest intellectual standards which are developed in the basic sciences. This influence works in many ways: some fundamental research students go into industry; the techniques which are applied to meet the stringent requirements of fundamental research serve to create new technological methods. The style, the scale, and the level of scientific and technical work are determined in pure research; that is what attracts productive people and what brings productive scientists to those countries where science is at the highest level. Fundamental research sets the standards of modern scientific thought; it creates the intellectual climate in which our modern civilization flourishes. It pumps the lifeblood of ideas and inventiveness not only into the technological laboratories and factories, but into every cultural activity of our time. The case for generous support for pure and fundamental science is as simple as that.[3]

These intrinsic intellectual and cultural values of pure science and its all-pervading character are readily recognized by the expert. The values are difficult to explain to a layman, but it is important to foster them successfully. In passing, it may be noted that Weisskopf also touched briefly on the role of the educational process as a link between science and technology.

Another important aspect of fundamental research is its essential place in the system of education. In its broadest sense, education involves the totality of effort related to acquiring new knowledge, preserving it in suitable form, and transmitting it to future generations, together with the thought processes involved. Very often, with obvious unfortunate consequences, the mere process of handing over knowledge as a dead, inanimate object is considered to be education; this happens in many of the educational institutions in India that stress uniformity and rote learning. The only way in which teaching can be brought out of this rut of routine, pedantic transmission of facts is by ensuring the accomplishment of significant research that leads to a tradition of penetrating, independent inquiry.

An enormous wealth of knowledge has been acquired by the human race and preserved in published form for easy access and use. Only a minute fraction of this knowledge can ever be imparted during the educational life of an individual. It is more important to impart the rationale of the scientific method: how one proceeds to formulate a problem and then to solve it; how one seeks and uses effectively the background knowledge that exists. I do not believe that there can be effective progress in this direction unless scientific research occupies a central position in university education.

Thus far, I have emphasized two arguments in support of an adequate allocation of resources for fundamental research – its intellectual and cultural significance and its inseparability from proper education. Another argument is that investment in science is immensely profitable in the long run. All those who have been concerned with the question agree that the returns are indeed spectacular. For example, it has been put by Powell that:

The present standards of living of the affluent nations today are essentially based on the pure science of the past, and the total investment on pure science up to

[3] Weisskopf, Victor F., "Why Pure Science?" *Bulletin of the Atomic Scientists*, 1965, Vol. 21, p. 4–8.

now, which has led to this, is equivalent to only about four weeks of their total industrial production today.[4]

J. B. Adams[5] has put it differently. He says that the cost of all basic research that has ever been done is barely equal to the current year's increase in the gross national product of the larger countries. Whichever way it is viewed, money spent on fundamental research is clearly an excellent investment, although a long-term one, and should not be regarded as overhead or luxury.

The arguments presented above and the views of Weisskopf, Powell, and Adams have been advanced in the affluent nations for support of pure science, which in many instances has reached the state of "big science" or, as Adams calls it, "megaloscience." However, they apply equally well to the developing areas. The problem is not the validity of the arguments, but rather how one can get them across to the men who matter – the ministers, parliamentarians, politicians, civil servants, and other members of the elite who have a voice in national development and the allocation of resources.

The difficulties of such individuals are readily understandable. In India today we have grim demands on food and agriculture (complicated by the vagaries of weather), defense needs, and priorities for industry in its many facets of power, transportation, materials, and production. These requirements are all related to the fabric of our everyday experience; the only question concerning them is: "What part of the national cake does each get?" This is the question that concerns our planners. Faced with multiple demands and with the background of a democratic system, it would be natural for them to make their judgments on the basis of the next question: "What immediate benefits will follow from this investment?" This method of judging a project has validity in certain circumstances. When applied to investment on scientific research, however, the question is neither relevant nor meaningful, as can be seen from the very definitions we considered earlier.

Because of this, those of us who are scientists have an important and continuing responsibility to educate the elite to an understanding that research is not the cake but the bread of daily life. It is for us to point out that the investment needed is very small – only about two per cent of the gross national product – and that there must be a gestation period of one to two decades, so that immediate returns cannot and should not be expected. We must also point out that science has self-generating characteristics; that once we get on the known exponential growth curve, the returns – based on experience elsewhere in the world – will be spectacular

[4] Powell, C. F. Op. cit.
[5] Adams, J. B., "Megaloscience," *Science*, 1965, Vol. 148, p. 1560.

indeed; and that scientific research is an intrinsic part of education and sets the pace and the standards for technology and development.

Often scientists seem to direct their efforts toward the division among themselves and among their areas of interest of what is, in fact, a subminimal total allocation for the various sectors of research. A cooperative effort on their part is needed to secure required allocations. I would like to consider briefly a possible approach to this problem. In general, developing countries are short of trained personnel in almost all domains of scientific endeavor. In fact, in many important areas there is a vacuum. In others, personnel exist only in limited numbers and often are of poor quality. Seldom are there areas in which there is a surplus of qualified men. The correct approach is, first, to support adequately those who are in the country, and in that way keep them from becoming part of the brain-drain; second, to fill the important gaps by a conscious channeling of talent and funds. The second approach is also relevant to applied research and development.

It is not too difficult to evaluate the amount needed per annum to maintain an effective "research group" at maximum efficiency. I have consciously introduced here the concept of the "group" for the following reason. For meaningful research to be accomplished in each area of scientific activity, a minimum requirement of equipment and research staff is necessary. In India there are cases in which investment on research programs becomes fruitless because it is subminimal and the group is not viable.

Scientific progress depends on men of ability; research groups must consist of, or be built around, such men. In certain areas the group can be small. An active group, adequately supported, can grow rapidly. It then becomes possible to take from it a part that has itself become viable and so can grow satisfactorily elsewhere. The total outlay immediately needed for scientific research will then be the sum of the outlays for each field; the latter will be the cost per research group per annum in a particular field, multiplied by the number of such research groups in the country. This pattern of allocation of resources should apply to scientific research in general and to fundamental research in particular.

The preceding rationale has relevance for groups engaged in applied research and development as well, because such groups are rare in the developing nations and it is absolutely essential that they be supported, if only to get into operation a self-generating cycle that can become part of the educational pattern. But one important aspect, which was defined earlier and which differentiates fundamental research from applied research and development, should be borne in mind – the latter two are characterized by definite practical objectives. In this sense, applied research and development have a mission to fulfill, and their support should come from the areas that will most benefit from their accomplishments. For example, the budget allocation for control of the population explosion (or for family planning, as it were) – a subject of vital importance for India – should include a certain amount for applied research in fertility, reproductive physiology, psychology, and other related subjects.

Each of the developing countries faces its own special situations and has its own requirements. Clear areas can be defined in which applied research and development will yield significant, tangible profits. It is even possible that a country may have intrinsic facilities for work in such areas. For example, as I have mentioned, tropical meteorology with particular reference to the monsoon are best studied in India, and an understanding is of profound importance for India's development. It should be a part of national science policy, and one taken up on a priority basis, to allocate funds for fields where gaps exist and consciously to encourage talent to move into these areas. A promising scientist might consider taking up applied research and development in areas particularly needed by his country if he knew that adequate support would be provided. Programs less relevant to the country's needs would get similar support only if they were of much greater merit.

In basic research, however, the deep motivation of a talented scientist working at the frontiers of human knowledge must be allowed to guide him to areas of importance to him. The expenditure will be an overhead on society as a whole and must be looked at from the viewpoint of its educational, cultural, standard-setting, and morale-building values.

Let us now consider certain other aspects of the problem through the medium of a concrete case history. For this purpose, I shall analyze briefly the origin and workings of an institution with which I have been closely associated – the Tata Institute of Fundamental Research in Bombay.

Today the Tata Institute has a total staff of about 1,200, of which approximately 300 are academic staff engaged in scientific research. These correspond to the faculty, teaching fellows, and graduate students at a typical American university. The remaining staff are either in the workshops, in electronic or chemical laboratories, or in the administrative and general supporting staff. Today the Institute is the National Centre of the Government of India for Nuclear Science and Mathematics.

About 25 per cent of the total staff are research workers. This compares reasonably with similar laboratories elsewhere in the world; it must be remembered that in India many procedures and processes have not yet been automated. I would like to emphasize that members of a properly chosen research staff are motivated and find it possible to keep themselves fully and usefully occupied; in other categories, clear-cut tasks must be defined. When ratio of research workers to total staff is low, the tone and morale of the laboratory can go down considerably.

The Institute is a little over 20 years old. It was founded in June 1945 on the initiative of Homi Bhabha. At the inauguration of the new buildings of the Institute in January 1962, Bhabha said:

While I was still working as a professor at the Indian Institute of Science in Bangalore during the Second World War, I noted that there was no scientific institution in India devoted solely to the fundamental research, especially in the newest branches of physics, namely nuclear physics and high energy physics. By fundamental research I mean basic investigations into the behaviour and structure of the physical world without any consideration of their utility or whether the knowledge so acquired would ever be of any practical value. Nevertheless, the support of such research, and of an institution where such research can be carried out effectively, is of great importance to society for two reasons. First of all, and paradoxically, it has an immediate use, in that it helps to train and develop, in a manner in which no other mental discipline can, young men of the highest intellectual calibre in a society, into people who can think about and analyse problems with a freshness of outlook and originality which is not generally found. Such men are of the greatest value to society, as experience in the last war showed, for many of the applications of science, which were crucial to the outcome of the war, were developed by men who, before the war, were devoting their time to the pursuit of scientific knowledge for its own sake. Radar and atomic energy are two examples of fields in which a vast body of established basic knowledge was developed into technology of immense practical importance, largely through the application in war time of the efforts of those who might be called "pure" scientists.

Secondly, the history of science has shown that "there is no genuine knowledge of the universe that is not potentially useful for man, not merely in the sense that action may one day be taken on it, but also in the fact that every new knowledge necessarily affects the way in which we hold all the rest of our stock."

The Tata Institute grew at the rate of about 30 per cent annually over the first ten years and about 15 per cent a year over the second decade. This provides some indication of the growth rates feasible in training highly skilled scientific manpower.

The first research projects at the Tata Institute were in mathematics and theoretical and cosmic-ray physics. It was clear to Bhabha that research in modern experimental areas was of the utmost importance, not only for its own sake and to provide the right balance for theoretical studies, but also because of the confidence that it could generate in the design, fabrication, and use of equipment. Bhabha's choice of fundamental research in cosmic-ray physics is a good example of an area in which, at relatively low cost, it is possible to participate in exciting new discoveries now at the center of the world's attention and to exploit national advantages, such as proximity to the geomagnetic equator, to the fullest extent. Also implicit in the choice was his intuitive judgment that it was rich in terms of new knowledge. Facilities were set up to develop and build indigenously those experimental items needed for cosmic-ray research, such as counters of various types and electronic equipment. The confidence and know-how thus generated made it possible, when the atomic energy activities of the country needed it, to set up programs for large-scale production of radiation instruments for survey and health physics and for a wide spectrum of electronic instrumentation, particularly in nuclear electronics.

If one takes the total annual budget of the Institute (for staff salaries, equipment, consumable stores, and other facilities, but excluding such major items of expenditure as buildings or computers) and divides it by the number of active research scientists, the total cost per scientist works out to about $5,000 annually. This can be compared with the average figure of $30,000 per research scientist per year in the United States and $85,000 in a laboratory such as CERN, which is concerned primarily with a very expensive area of basic research – high-energy elementary particle and nuclear physics, in which large accelerators are used. The expenditure of $85,000 per scientist a year is for "big science," but in India today *all* research is "little science."

From the above it is clear that the magnitude of expenditure for a first-rate center of fundamental research need not be extraordinarily high; the same type of work is much less expensive in India than in many other places in the world. Genuine fears have been expressed that countries like India might go in for "big science," involving expenditures as high as $100,000 per year per scientist. I would agree entirely that this should not be done. However, expenditures on "little science," which require only one-twentieth of this amount, certainly can be, and should be, supported.

Bhabha proposed the establishment of the Tata Institute of Fundamental Research to the Chairman of the Sir Dorab Tata Trust in a letter dated March 12, 1944. In that letter Bhabha emphasized several points that relate closely to my discussion. He said:

> It is absolutely in the interest of India to have a vigorous school of research in fundamental physics, for such a school forms the spearhead of research, not only in less advanced branches of physics, but also in problems of immediate practical application in industry. If much of the applied research done in India today is disappointing or of very inferior quality, it is entirely due to the absence of a sufficient number of outstanding research workers who would set the standard of good research.
>
> The Institute will be affiliated to the Bombay University. The Bombay University could send its advanced research students to the Institute's laboratories to work

for their doctorates, for attending the few advanced courses and lectures that would be given on behalf of the University.

Financial support from Government need not, however, entail Government control.

The Tata Institute's basic aim is to be a center of excellence in those fields in which it carries on research activity. The implementation of this aim is important for several reasons. First, it provides a place where the country's potential scientific leaders can find opportunities to participate in first-rate research. If there were no such places, these men would go abroad to find opportunities. Having spent many years abroad, perhaps during the most impressionable periods of their lives, and with no satisfactory place to which to return to continue such activity, these potential leaders would be lost to the country permanently. Giving them fine research facilities in their own country has a special significance; while they are working they remain emotionally and culturally a part of the country and its aspirations.

Not only is the research of such men important; so, too, is the role they play in the broader context of national development. While it is true that some leaders confine themselves to their personal scientific interests, many more – particularly if they are deeply moved by the environment in which they live and work – find ways of exercising their intellectual abilities and their training in the scientific method to provide badly-needed leadership on a much wider front.

It is important to have many such centers in various scientific disciplines in a country; the actual numbers and locations may be a matter for discussion, and will vary with the country and its needs. A center can be the scientific department of a university, part of a university (which the Tata Institute is), or a separate national laboratory (which the Tata Institute also is). To judge among these possibilities one would have to take into account many details that I shall not go into here.

When adequate research facilities and support are not provided in a country, one encounters the brain-drain. Generally, the best scientists get jobs elsewhere most easily, and the country's scientific leaders are lost. Often scientists engaged in specific activities are forced to emigrate because these areas are not supported in their own country, while the demand elsewhere may be great. This would indicate either that the areas in question are not considered important to the country or that support is not given for other reasons.

An equally important, but much less-discussed, phenomenon is that of the "internal brain-drain," i.e., scientists who are unable to find positions and facilities commensurate with their training and abilities and who are forced into positions that make no use of their background, or who work under adverse conditions that make them comparatively ineffective. These situations are encountered in all the developing nations.

Homi Bhabha believed – and I share that belief – that if one could demonstrate that a country such as India could build institutions which would hold their own places in the world, institutions in which one could have genuine pride for their quality of achievements and standards, a feeling would be generated that would be of tremendous practical and psychological importance to the country as a whole.

Implementing Change Through Science and Technology

VIKRAM SARABHAI

THIS ESSAY explores six questions pertinent to government policy for science in a developing country. First, what is the most appropriate way to take science to industry? Second, how does one create centers of scientific research and development in new fields? Third, what administrative practices are appropriate for government in science? Fourth, how is research to be viewed—as overhead or as investment? Fifth, what is meant by planning research? Finally, what can government do to implement change through the application of science and technology? At the outset I will present some summarized case histories of experiences relevant to problems of implementing change. These will help give flavor to some general comments that follow.

In 1948, I had the responsibility of establishing the operations of the Ahmedabad Textile Industry's Research Association (ATIRA), for which industry and government shared costs. We were given a great deal of money, judged by standards then prevalent, but no one had a very clear idea of what should be done. Questions put to managers and technicians within industry did not provide specific answers, but convinced us that ATIRA could be most helpful if it supplied skills and insights and encouraged ways of looking at problems that were complementary to those generally available within industry.

Our core group in ATIRA started off with a mathematical statistician, a social psychologist,[1] a high-polymer chemist, and a solid-state physicist—all

[1] Dr. Kamla Katur Chowdhury, whose paper on "Social and Cultural Factors in Management Development in India," prepared for the International Labour Organization meeting of experts in November, 1965, explores some of these questions from the useful vantage point of the social psychologist. (Management Development Series, #5, 1966, pp. 52–64.)

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fresh from advanced research in universities. All, including myself with a background in nuclear physics, were under 30 and none had had previous experience in textile technology. Initially, we felt our task was to observe operations in industry, hoping that in understanding technology we would be able to apply the scientific method of analysis, to ask some basic questions on why things were done as they were, and perhaps to help shrink the time-lag between discovery and implementation of new developments.

We ran into serious problems when we entered an organization at the invitation of its director. We were greeted with attitudes reflecting deep insecurity, often even expressed hostility, on the part of people working permanently at different levels in the company. We succeeded, in some measure, when we were able to become members of a joint investigating group and had largely overcome our identities as outside experts. We found, moreover, that visiting experts who were eager to achieve demonstrable results in short periods, who had no long-term commitments to the project, and no responsibility to live with the results of change, were often most disruptive.

The following conclusions from this experience stand as the most important.

1 In implementing change, we must apply ourselves to people before we can apply ourselves to problems.
2 The biggest obstacle to innovation most often arises from social factors within organizations rather than from the absence of technological know-how or equipment.
3 Organizations that were already leaders in the industry, and presumably had the over-all climate that was conducive to change, were generally also the ones that could benefit most effectively from their association with ATIRA. In other words, the companies that could do most with innovations were the ones least able to receive help from outside experts.
4 For relating science to the real problems of society and for the application of results, a cooperative research association using industry as a partner has many advantages over laboratories that are governmental or quasi-governmental in character.

When we look at the development of science through governmental or quasi-governmental organizations, we also find numerous problems. Homi J. Bhabha described some of these in two case studies. In quoting his observations, I should emphasize that today there is increasing realization of measures needed to remedy some of the defects he highlights.

The standard method of planning laboratories and filling posts is often forced on many by the administrative and financial requirements of Government. A

Planning Officer is appointed for planning the work and building of each laboratory. The plan is usually drawn up on the basis of the work of similar laboratories abroad, divided into divisions and sections, and an estimate of the staff required made on this basis. An attempt to fill the posts is then made on the basis of advertisement, and invitation also in the case of the seniormost appointments. While this method of setting up a laboratory might give reasonably satisfactory results in a developed country in which science is already an important activity and a large number of scientists already exist in the universities and in other public and private laboratories and research institutes, it has serious disadvantages in a country in which organized science is still in its infancy and the number of available outstanding scientists limited. . . . A result of following this method has been that a number of good scientists have been drawn away from the universities into the national laboratories, leaving the universities weaker thereby. . . .[2]

Bhabha also discussed the role of scientific administration, pointing out that while India inherited "extremely competent administrative services" from pre-Independence days, those services were geared to industry or to law, for example, rather than to science. This lack, he said, was "a bigger obstacle to the rapid growth of science and technology than the paucity of scientists and technologists," who are less effective if they do not have proper administrative support. Bhabha maintained that as long as the government spent large sums to support research and development, it was in the government's interest to devise efficient administrative and financial procedures for scientific institutions in order to receive a maximum return on its investment.

The application of science to the real tasks of a nation reveals the need for an interactive type of leader, rather than a "boss," to be most effective. He is required to relate himself to the work of others, to give as well as to receive. In Indian society scientists encounter a curious difficulty in accomplishing useful, tangible results. Intellectual endeavor is placed on a very high social scale, but those who are engaged in it are regarded as unfaithful if they should be concerned with day-to-day, practical affairs, including their own standards of living and job security.

Research scientists in national laboratories or academics in universities are looked down upon if they engage in outside consultation or if they choose to augment their income from task-oriented projects of a practical nature. We implicitly promote the ivory tower, and the alienation of persons of insight from "those who do things" is encouraged by such an attitude. This is cause for alarm, because those posing the basic questions are the ones best able to do the applied work. In most situations, identifying the real problem goes a long way toward solving it.

[2] Bhabha, Homi J. "Science and the Problems of Development," *Science*, 1966, Vol. 151, pp. 541–548.

To create conditions under which science and scientists can be applied to the real problems of society, we must encourage scientists to interest themselves in problems outside their fields of specialization. To be sure, the opinion of a scientist should not be given special weight in fields other than his own. However, a person who has imbibed the ways of science injects a new viewpoint into a situation; hopefully, he may also offer a degree of enlightenment on the approach to problems, and thus provides a valuable kind of leadership.

This does not mean getting scientists onto diverse committees. There is plenty of that. However, we must make it possible for them to work in their own fields of specialization in addition to undertaking, or collaborating in, other related areas. Innumerable situations in which this is possible lie on the doorstep of every individual. They could be related to improving curricula and methods of education, to setting up local industry or promoting the productivity of farms, to local and regional planning, to implementing programs for population control or community development.

In Ahmedabad, for instance, a Group for the Improvement of Science Education was begun four years ago. This group consists of teachers from schools, colleges, and research institutions, and some gifted students, brought together by a strong personal motivation to improve understanding of science and the standards of education. They are ready to question, to innovate, and to share experiences. At each level, wherever they work, they provide the type of leadership we are considering here.

We know through experience that conditions of work in specialized scientific fields in India rarely match the facilities available in several other countries. It is often frustrating to strive against heavy odds. Some scientists leave the country; however, those who can apply their insights to the problems of the community and the nation discover an exciting area of activity where effort is rewarding even though the results may come slowly.

What should we do to provide the opportunity for such leadership? Attitudes that segregate scientists and intellectuals from the rest of the world will not change quickly. We are not likely, in the near future, to provide scientists and teachers with job opportunities and service conditions that are on a par with those enjoyed by administrators. Nevertheless, we can provide encouragement to those who will accept responsibilities for real tasks, big and small, while they continue to do their own work. We can, moreover, work to secure acceptance of the notion that such task-oriented activity, seriously undertaken and with a well-defined objective to be realized in a given period, should receive financial reward that will ameliorate the total situation in at least one important aspect.[3]

[3] The preceding seven paragraphs have been adapted from Vikram Sarabhai, "Leadership in Science," *Yojana*, February 6, 1966, pp. 11–12.

Finally, we come to the question of government policy on the application of science and technology for development. This involves us in the area of government planning for science – assigning the resources required and relating these to other national priorities.

India has recently been spending about 0.2 to 0.3 per cent of its gross national product on research, compared to a figure of 0.8 to 1.5 per cent spent in other countries that either have reached a take-off point or have already attained a developed economy. The provision that has been proposed for the draft Fourth Five-Year Plan will not appreciably increase the low percentage allocation for research. This can be interpreted to mean that science is still being perceived as overhead rather than as investment. Obviously, the responsibility for this state of affairs lies as much with scientists as with elite groups who determine the role of science in our society.

What can the government do in these circumstances? Here are several possible steps.

1 Keep up the open-ended support of those individuals and organizations that have demonstrated the quality of excellence in their work.

2 Where there are major deficiencies in scientific effort in particular areas – as, for instance, in the biological and the earth sciences or in agriculture and engineering – special support must be given to scientific groups for task-oriented development projects that are subjected to prior political decision-making.

3 Prepare a list of developmental and applied research tasks to provide a basis for initiative. First, we must identify specific tasks on the basis of preinvestment studies made quantitatively, competently, and without ideological bias. The studies should evaluate the social, technological, and economic implications of the choices that may be possible in accomplishing the tasks. This exercise requires sophistication as well as a keen awareness of contemporary and advanced science and technology, and is one which calls for the collective attention of the best interdisciplinary groups the nation can assemble. An international team may sometimes be even more effective than one which comes from a single social and cultural background. The studies should concern themselves with such things as organization, personnel, and administrative practices for implementing change on the basis of political decisions to be made. Second, we need test-marketing operations to study the response of the groups affected by change brought about by the application of science.

4 Undertake measures to create awareness among the elite of the nation about the scientific method and the implications of science for society. Included here are politicians in government, in parliament, and in

party organizations; civil servants and administrators; industrialists, merchants, and financiers; technicians and managers; professional soldiers; and the scientists themselves. We must understand how this is to be accomplished. Essentially, it calls for leadership by scientists, engineers, and technicians of the country if they are to emerge from their encapsulated existence. Only then is there hope of moving ahead in applied science and of making a major investment in it.

Such endeavors would give a new meaning to planning for science and development, and should be the immediate objectives of the science policy of the government.

Problems Relating to the Utilization of Research Results

SALIMUZZAMAN SIDDIQUI

IN THE APPLICATION of science to economic development, the most intractable problem facing the developing countries is the series of bottlenecks that hold up the utilization of research results. They produce a grave and frustrating situation for the national research organizations of these countries, because there is an increasing insistence that the large funds expended on them should be justified by demonstrable economic returns. Even excluding this compulsion for cost-accounting, applied research too often appears pointless to scientific workers in developing countries if its results are not closely integrated with the relevant sectors of economic development. To cope with this situation, some of the countries have established research utilization boards, furnished with adequate funds, to promote industries based on research in various applied fields. Such arrangements may have a certain advantage for countries with highly developed industrial structures, but they seem to be of doubtful utility in those which have a comparatively limited industrial potential.

The Pakistan Council of Scientific and Industrial Research has set up a Research Utilization Committee on which there is a broad representation of scientists, industrial economists, relevant governmental departments, and development corporations. The offers received from the industrialists in response to public advertisement are scrutinized by this Committee, and the processes are then leased out to suitable parties against the payment of agreed premium and royalty. Following the allocation of a process, the Council provides every possible assistance in setting up the factory, and in some cases has actually run it in the initial stages of production with the help of its own technical and engineering personnel.

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The experience gathered over a number of years by the Council shows that, if research processes are to be converted into industrial production, the responsible research groups must be closely associated with the projects all the way from the laboratory workbench and pilot-plant studies to actual commercial exploitation. According to the procedure followed by the Council, a process worked out in the laboratory is subjected to pilot-plant investigations to establish its economic requirements and the optimum conditions for production. In the course of these investigations, the resulting products are sold on a cost-plus basis to assess the reactions of consumers to price and quality; necessary improvements are then made in the light of that assessment. Such a procedure, although somewhat protracted, ensures the acceptability of the research products in the market and attracts prospective industrialists.

More than 20 processes developed under the aegis of the Council since its inception in 1953 have been leased out to industry, which has made a total investment of about $6.3 million or Rs 30 million. Some have already gone into production; others are expected to reach that stage in the course of the next two years. This certainly does not indicate that the CSIR in Pakistan has made a sizable impact on the industrial development of the country. However, once a beginning is made on the right lines and the Council has established its reputation for a down-to-earth, practical approach to science and its application, it should be able to overcome many obstacles it has had to face in putting across some of its larger-scale commercial exploitation projects.

An idea of the kind of difficulties that block proper utilization of research results can be found in the mechanics of the first phase of industrialization in developing countries. The countries recognize that in this phase they must buy foreign technology at a heavy cost – as, for instance, was done by the Pakistan Industrial Development Corporation – to raise the industrial status of the country. However, it is not fully realized that this cannot be the whole answer; we must invest – and invest heavily – in scientific and technical research. It may take a long time for that research to exercise its impact on development; without it, however, it will be impossible to harness our human and material resources fully. Unless these resources *are* harnessed, we shall continue to be underdeveloped entities.

Yet another aspect of the situation merits consideration. In the present phase of industrial development, the entrepreneurs of industry settle for "turn-key," or push-button, jobs done for them by foreign firms in the manufacture of such well-established commodities as cotton textiles, jute goods, and petro-chemicals, rather than accepting new processes and products evolved by the research organizations of their own country. Along with this goes the buildup of vested interests, which generally exert a great deal of pressure against the use of products based on indigenous resources and processes.

The CSIR in Pakistan is also charged with the responsibility of solving some industrial operational problems that are normally undertaken by research associations in the industrially developed countries. The utilization of such operational research results is fairly well assured, and efforts are being made to strengthen this activity further by establishing a full-fledged Industrial Liaison Division.

Against this background, it may be appropriate to cite a few case histories of research and development. These reflect some of my own experiences.

Studies of the marking-nut (*Semecarpus anacardium*, Linn.) establised that its main constituent is a catechol derivative with a long, unsaturated side chain.[1] Because the chemical structure is closely related to urushiol, the principal constituent of the Japanese lacquer varnish, it was suggested that it might serve as a starting material for the production of enamels and varnishes. This suggestion was reported in a paper published in 1931, which was called to the attention of some of the institutions interested in industrial research. There was no reaction until I raised the issue when I joined the CSIR in 1940. Within a few months it was possible to establish that the material could be used to produce certain varnishes and enamels for stoves. Then, because these materials were in short supply during the Second World War, the process was almost immediately taken over for development by one of our leading industrialists.

In another case, the first paper reporting the isolation of a series of alkaloids from the now-famous roots of *Rauwolfia serpentina* was published in 1931.[2] Nearly 20 years elapsed before one of its alkaloids was established as a potent drug in the treatment of hypertension and mental ailments. Only during the last few years has ajmaline, the principal alkaloid of the plant, been recognized as an important drug in the treatment of cardiac arrhythmias of various origins. This time-lag between research and the development of such important therapeutic agents has been caused mainly by the lack of adequate facilities for interdisciplinary research and by the lack of an entrepreneurial spirit among industrialists.

Here is one more example to illustrate the handicaps research organizations of developing countries must overcome to bring about the use of research results. Studies that have extended over about eight years under

[1] Pillay, P. Parameswaren and Salimuzzaman Siddiqui. "Chemical Examination of the Marking-nut (*Semecarpus Anacardium*, Linn.), " *J.Ind. Chem. Soc.*, 1931, Vol. 8, pp. 517–525.

[2] Siddiqui, Salimuzzaman and Rafat Hussain Siddiqui. "Chemical Examination of the Roots of *Rauwolfia Serpentina*, Benth.," *J. Ind. Chem. Soc.*, 1931, Vol. 8, pp. 667–680.

the Pakistan CSIR have resulted in a series of chlorinated insecticides based on indigenously available hydrocarbons. Laboratory tests and field trials, carried out in association with the Department of Agriculture, have shown them to possess the same amount of pesticidal activity as Toxaphane. They have the further advantages of extremely low mammalian toxicity and of being heavily synergized by the addition of small quantities of some of the more potent pesticides, such as endrin and Gammexane.

The importance of this development to the agricultural productivity of the country may be gauged by the fact that Pakistan has been importing about $10 million worth of pesticides yearly; these can take care of barely 10 per cent of its plant protection requirements. Nonetheless, development of our own pesticides has been delayed over the years because vested interests import them and lack faith in indigenous research effort. The struggle is on, however, and one can only hope that, through the sheer pressure of the economic situation, these products will ultimately be taken over for large-scale production.

This essay has dealt mainly with the utilization of research results in industry, because machinery for liaison and extension services in agriculture is fairly well organized under relevant governmental departments. In Pakistan, further strengthening and rationalization of this machinery is projected under the Agriculture Research Council, in close association with the agricultural departments of the central and provincial governments. However, in agriculture, industry, or any other field of scientific research, the really critical link is that which assures actual, prompt, and widespread use of the results of research.

Use of Science and Technology in Developing Countries: Some Problems and Approaches

Y. NAYUDAMMA

It was Jawaharlal Nehru who said: "Modern life is an offspring of science and technology. . . . It is now patent that, without science and technology, we can't progress, and it is an inherent obligation to participate fully in the march of science, which is mankind's greatest enterprise today." Science and technology and their efficient use are critical to the economic growth of any country. The need is all the greater in developing countries, which have so much to accomplish in advancing the welfare of their people.

However, science and technology must be utilized efficiently and effectively in advancing that welfare. In fact, utilization constitutes the basic problem. This, in turn—as this essay attempts to show—is complicated by a number of factors that occur throughout developing societies and inhibit use of research. The essence of the problem is to develop—in the scientific research worker and the potential user of scientific research, whether he be an agriculturist or an industrialist—a common frame of reference, a common way of looking at technological problems and their solutions. Because of the circumstances in developing countries, the scientific research worker must take the initiative to see that the potential user is made fully aware of the possibilities that lie in research.[1]

Countries differ widely in levels of income and technology, in industrial

[1] These considerations are developed further in Y. Nayudamma, "Promoting the Industrial Application of Research in an Underdeveloped Country," *Minerva*, 1967, Vol. V, pp. 323–339.

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structure, size, technical and skilled manpower, the ratio of indigenous to imported technology, and other factors that affect research returns. The yield also depends upon the proper identification and definition of a problem. Research problems should be chosen that are relevant to economic growth, reflect national priorities, and are properly oriented toward raw material resources. Effective facilities for design and engineering and for scaling up production processes are also important.

The developing countries have additional problems. A number of social and material obstacles must be overcome if research is to be advanced. A strong faith in science as contrasted to deep-rooted dogma, a commitment to use science and technology even if it means breaking down tradition, the proper type of education, the development of the questioning attitude – all are required ingredients for building a scientific atmosphere in which research can yield results.

In achieving the most favorable atmosphere for this goal, each developing country must confront problems peculiar to it. However, a number of factors common to most of those countries affect such efforts. Some of these – such as rapidly growing populations and extensive unemployment and underemployment – are well known, as are such similar problems as lack of skilled labor, widespread small-scale industry, limited industrial development, and the like. These factors are compounded by shortages of capital and of technical skills, a lack of tradition in using research results to solve technical problems, and the inevitable role of tradition in a society which is only in the earlier stages of modernization.

Quite apart from the scientific temper in the community at large, the atmosphere inside research laboratories may change drastically in developing countries such as India. Outmoded organization, undemocratic procedures in the conduct of research, improper planning and emphasis on prestige projects, lack of encouragement of a competitive spirit and a questioning attitude are among the circumstances inhibiting productive work within a scientific laboratory. Excessive respect for age, low pay structure, and heavy administrative, teaching, or other loads for a research worker are related factors that must be corrected. How to encourage a good researcher often does not pose as much of a problem as how to get rid of a bad one.

The flow of research results into the industry of India and many other developing countries is often slow, irregular, and inefficient. Although the tempo of research activity has increased considerably in India since Independence, much needs to be done before the effective and systematic utilization of the fruits of the "revolution in science and technology" will meet the demands of the "revolution of rising expectations." Not only is there a long time lag between research findings and their use; often research goes completely unused. The lack is in effective communication and dissemination of scientific knowledge to industry and to the community at large.

A number of factors can contribute to greater use of research results by industry. Proper identification of projects – selected according to a scheme of priorities that will make them most relevant to economic growth – is essential. The efficient conduct of research and its development to some logical conclusion – with sufficient developmental experience, including necessary design and engineering data – are also essential. By the same token, it is essential that new processes or products be developed to meet the various demands of industry in the large, small, and cottage sectors.

These kinds of conditions depend upon an active dialogue between the research institution and the industry it seeks to serve. The industry should have as intimate an association as possible with the work of the research institution, both in the selection of research projects and in the proper communication of the results. There are, of course, factors outside the immediate control of research institutions that have a direct bearing on effective application of research. Among these is the ability of the industry to absorb the results. This is particularly significant in developing countries, because the relatively low levels of technical and managerial skills and financial resources, particularly in traditional fields of industrial activity, make it more difficult to use new technology.

An industry – particularly in the cottage and small-scale sectors – often has limited capital resources with which to adopt new technology. Frequently, there is a lack of competition in a particular industry because the consumer demands far exceed industrial production capacity. Consequently, there is little incentive to use something new and better because there is never any difficulty in disposing of the industrial output. Limited foreign exchange – if machine tools, for example, must be imported from abroad – uncertainty of raw materials supply, and unwillingness to take risks and indulge in the usual entrepreneurial hazards of industrial enterprise are other roadblocks.

Often the situation affecting use of indigenously developed technology is further compounded by the availability of imported technology (often along with foreign capital and, therefore, foreign exchange). Consumer preference may also be a factor – that is, preference for foreign goods over those of local manufacture.

At one time or another many a developing country faces the question of whether to import technology. There are powerful attractions, in addition to consumer preference. Industry is not certain of the exact time when indigenous technology will be available to it, or at what stage of development, whereas foreign technology can often be secured relatively quickly on reasonable terms. This, of course, saves time and uncertainty. It also presents fully developed manufacturing processes, often with the necessary equipment already designed and even fabricated, and internationally known brand names for ready sales.

However, the indiscriminate import of technology will, in the long run, inhibit the developing country's progress. Foreign technology is more suited to conditions in the countries in which it was first developed, not necessarily to the resources and skills of other peoples. Sometimes outdated and outmoded processes and equipment are imported, and unless there is contact with indigenous research, local industry will be continuously dependent upon foreign know-how.

While no country can afford to be totally self-reliant, a developing country should use foreign technology rationally. If technology is readily available or likely to become available in a reasonable time through indigenous research and development, or if foreign collaboration already exists in a particular field, the import of further know-how should be discouraged. Once foreign collaboration is permitted, however, capacity should be built up through multiple units based on this knowledge, so that it will be available for other purposes. Such an approach will create competition among different industrial organizations and increase productivity, apart from offering large savings in the import of components and replacement parts, maintenance services, and the like. Steps should be taken simultaneously to assure dissemination of knowledge about the design of the imported equipment.

Instead of each entrepreneur seeking separate technical collaboration with foreign firms, a common approach through a single agency should be made to save foreign exchange, to lead to standardized plans and equipment, and to encourage a healthy competition among different firms. Each unit will then be working under similar conditions with the same process, and its competitive advantage will depend upon the degree of efficiency demonstrated.

In a developing country like India, science will flourish and grow rapidly only with strong government support. For effective utilization of research results, the government may have to use persuasion or take other appropriate action by administering different remedies for different circumstances. Among the forms of government action that could be helpful are establishment of policies that affect the import of foreign technology, tax incentives to those who provide industrial-risk capital, and support of production based on indigenously developed technologies through subsidy or trial orders from government ministries and departments. Most important, in addition to the obvious consideration of adequate support for research itself, is sufficient assistance in the development phase of industrial research. Unless a particular product or process can be carried through the pilot-plant stage so that reliable data on engineering and design can be accumulated, there is little hope that industry will take over indigenously developed technology.

The government also has a role to play in creating conditions that will interest industry in new technology. If, for example, action is taken against restrictive practices and protected markets, industry will be given a much stronger incentive to think of research as a means of improving its competitive position. Sometimes a subsidy to help introduce a new industrial product will be important because the size of local demand may be small at the outset, especially if there is strong competition from imported goods of similar character.

The government role should also include encouragement to industry in initiating cooperative research associations or research departments by providing tax incentives or partial support. The establishment of technical information centers—on an industry basis and in different regions of the country—for diffusion of scientific and technological knowledge would also be useful. Related in character are technological clinics, which should be conducted in every major region or state of the country to provide consultant help to industry in dealing with day-to-day problems. This, in turn, implies adequate training facilities for extension workers who will carry on field demonstrations and otherwise serve as links between industry and research.

Of course, all of this depends on government leaders who are resolute enough to make clear and prompt decisions and to implement them. Often the lack is not so much one of proper plans or finance as of forceful leadership.

Communication, however, remains the main problem in inhibiting use of research by industry. There is plenty of knowledge in the world today. Now it must be taken to the very doors of the ignorant and illiterate to show them conclusively that research in science and technology will bear fruit and will raise their living standards. This depends on effective extension work by research institutions. Every conceivable extension technique should be tried, and a corps of dedicated and devoted service workers should be established by each research laboratory.

Several qualities are required of such workers. Perhaps the most important is a sense of humility in approaching those whom they seek to help. Even in traditional craft-based industry there is often great skill, common sense, and adaptability to local resources and circumstances. An understanding of the psychology of industrial workers, their traditions, and their environmental conditions is essential. The extension service worker must be able to live with the people he would teach, eat with them, work with them, and talk to them in their own language.

Selection of technological processes appropriate to the conditions of the particular industry being served is also important. The extension worker must sometimes move slowly to create initial confidence before introducing newer and better methods, particularly those that are radically different. If the worker is effective in demonstrating a good economic return for a new technology, he will have little difficulty persuading persons to adopt it. The technology should be offered on the basis of "profits you take, losses I take" – a practice that is being followed wherever possible in the extension work of the Central Leather Research Institute in Madras.

Any new process must be demonstrated virtually from raw material to finished product. This is especially true in small-scale and cottage-sector industrial establishments. In short, the industrial scientist, working directly with or through the extension service worker, must be able to present his findings in a fashion understandable to workers at all levels of industrial activity.

As an example, the Central Leather Research Institute offers to cottage tanners packets of chemicals in different colors. The tanner is asked to use the contents of the packets at different intervals in his traditional method of tanning. This method of approach is better than telling him to adjust the $_{p}$H or tannin content, or giving some other technical explanation of the chemistry of leather tanning. If he follows the procedure that has been suggested to him in simple terms, he will get a better quality leather. This will bring him better economic returns, and he will then ask for more packets.

A single demonstration is rarely sufficient. Follow-up action is essential to ensure that the new product or process is actually being put to use. One such action is a "tracer technique." This procedure has been used by the Central Leather Research Institute, and makes it possible to tell whether industry some distance from Madras, where the Institute is located (Bombay or Jullundur, for example) is actually using a new method. A new process involves the use of a small amount of CLRI-brand material, available only through the Institute. If, after the initial demonstration by the extension service workers, there is no demand from Bombay or Jullundur for this material, the extension demonstration is clearly a failure and some remedial follow-up steps are necessary.

To make extension services readily available, the research institutes serving such specific industries as leather must set up regional extension centers in those areas in which the industry is concentrated. The Central Leather Research Institute has such centers in Calcutta, Kanpur, Bombay, Rajkot, and Jullundur.

Another effective extension technique is practical training programs for technologists from industry. At the Central Leather Research Institute this is called the "Guest Tanner" program. The scheme makes it possible for a practicing tanner to spend from several weeks to months at the Institute, learning about the work going on there. Whenever possible during this time, the Institute arranges to send one of its staff to work in the tanner's firm, thereby enabling him to acquire a realistic picture of the problems of actual production. This promotes a closer association between the Institute and the tanner in the future.

The Central Leather Research Institute insists that the technologist work with his own hands in learning new processes. Furthermore, it is the technologist who gives a certificate to the Institute, not the Institute that gives a certificate to him; it states that he has learned all the Institute can offer and that he can use.

In extension work, it is essential that the senior officials of the research institutions have contact with all levels of industry, including the smallest-scale enterprises. This is important both to demonstrate the institution's active interest in what industry is doing, and to give the senior institute officials means of keeping abreast of day-to-day industrial problems. This helps orient the laboratory's research program to meet actual industrial needs more effectively.

In the Central Leather Research Institute the director himself makes frequent tours of different states. The typical pattern includes contacting the state's director of industries, its director of the small industries institute, and officials in other organizations connected with leather industry – the Khadi Commission, for example, which is concerned with handicrafts – and then setting off on a tour of the state. The presence of the Institute director helps ensure the presence of senior state officials and creates considerable impact in the villages. Each month a new state is visited in this fashion.

Another technique used by the Central Leather Research Institute is to send Institute staff to an industrial concern that has been running at a loss and putting it on a sound economic, as well as scientific, basis. This is a powerful demonstration, indeed, because it shows clearly that good scientific methods bring good economic returns. A related effort is to establish industrial research associations or cooperative enterprises that will use the results of scientific research. For example, a company of tanners, by tanners, and for tanners has been started with the express purpose of taking advantage of research carried out at the Institute. This company produces leather accessories that have always before been imported. When the company uses a process developed at the Institute, the latter receives royalties. These are used to further research on leather technology.

A continuous effort must be made to find ways and means of bringing industry as close as possible to the research institute. Industrial officials and workers should be invited to the research institute, serve on its executive councils and governing bodies, draw up research plans and evaluate them, and so on. To the degree possible, students and former colleagues from the institute should be "planted" throughout the pertinent industry, as well as in state and national governmental agencies concerned with that industry. If this kind of network exists, it is much easier for the director of an industrial research laboratory to know of any new industrial or governmental plans that should be reflected in the research work of the institute for which he is responsible.

Other efforts of the Central Leather Research Institute include an Indian Leather Fair, which has resulted in the establishment of a permanent organization to hold periodic symposiums or conferences for research workers and industry. One such symposium – on better utilization of indigenous hides and skins – led to the establishment of the Indian Hides and Skins Improvement Society, which is affiliated with the International Hides and Skins Improvement Society.

Like any other investment and like any other human endeavor, yields of research need evaluation in order to take stock of achievements, to improve upon present performance, and to plan more realistic programs for future research. The really critical question is whether it actually is possible to make a meaningful evaluation of research yields, and if so, in what terms, monetary or otherwise, and with what degree of accuracy.

Research results in patents, inventions, publications, equipment design, new technological processes, and even new technical training. In project-oriented research, the measurement of input to research is not difficult; the measurement of output is much more so. Returns on research are of several kinds – direct and tangible, indirect and intangible, potential and intrinsic. The tangible results are greater productivity, less waste, reduced production costs, and new machines, processes, uses, and products, as well as better quality. The intangible outputs are the strengthening of the infrastructure of knowledge; making skilled personnel available; controlling quality; introducing better test procedures; presenting consultation services, surveys, plans, and programs; and spreading scientific temper in the community.

It is also useful to remember that the economic growth of a country depends not only upon the research yield, but also upon the availability of capital, raw materials, power, labor, risk propensity, and other factors far beyond the scope of the research laboratory. An exercise in evaluating research yields in the national laboratories of the Council of Scientific and Industrial Research has clearly indicated the many difficulties in arriving at a proper methodology. Evaluation varies from project to project, from laboratory to laboratory, and at best can give only indicative and qualitative, not precise and quantitative, results. Yet evaluation must be attempted to provide guidelines for realistic programing of further research.

There is a great amount of knowledge in the world, and application of that knowledge to secure greater material benefits that will meet the "revolution of rising expectations" of people throughout the world is most urgently needed, particularly in the developing countries. Only the effective utilization of science and technology can accomplish it.

Wasted Investment in Scientific Research

MAHBUB UL HAQ

WE OFTEN HEAR LAMENTS about the meager resources being devoted to scientific research in South Asia, but little is said about the concrete benefits the countries are receiving from their investments. A number of other contributors to this volume have talked about the priority that should rightly be given to science, but few have tried to indicate how priorities are to be fixed *within* scientific research in the light of the current and growing requirements of their countries. During the years that I have been associated with the Pakistan Planning Commission, I have been conditioned to deal daily with questions of costs and benefits and of priorities and misallocations. This essay attempts to explore such mundane issues in a fashion that will not always be popular in scientific circles in South Asia, but my intention is to raise issues, not to offend.

There is a curious imbalance today between the demand for and the supply of scientific personnel in India and Pakistan. On the other hand, we hear loud complaints from economists that critical skills are lacking and economic growth is being retarded. For instance, Pakistan's Third Five-Year Plan complains of a shortage of 10,000 engineers and similar shortages of skills in other scientific fields. On the other hand, we have the familiar phenomenon of unemployed scientists roaming the streets. It is not uncommon to find in India and Pakistan large numbers of engineers and doctors who cannot find employment, who take on positions not entirely appropriate to their training, or who leave the country.

These countries also depend heavily on imported skills, particularly on foreign consultants associated with technical assistance programs. For example, Pakistan is spending over $100 million a year on foreign consultants; this is more than one per cent of its total national income. Compare this to some of the figures frequently cited about the .01 per cent or

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.02 per cent of national income being devoted to scientific research in various countries of South Asia. Clearly, something is wrong. In my opinion, the error lies in the content of scientific research and inappropriate priorities within the educational sector. A large proportion of even the meager funds presently available is being wasted.

In the first place, there is the error of overspecialization. In South Asia, generally, there is a shortage of middle-level technical personnel. The overseer on a road project, the supervisor on a construction job, and paramedical personnel, such as nurses and health visitors, are in short supply, whereas the system concentrates on highly qualified engineers, doctors, and architects who may not be required by society in the numbers in which they are produced. There is a certain craze for imparting the latest and the "best" education to students, irrespective of demands of the economic system. As a result, we have the strange spectacle of these poor countries creating skills for the export market.

To quote only one example, about 20 per cent of the doctors presently trained in Pakistan seek employment abroad. Only a short while ago, we had a system of producing middle-level doctors to serve primarily in rural areas. The program was abolished in the mistaken notion that, in this age of modern science and technology, society needed only people with advanced training in medicine. However, the present distribution is so uneven that there is only one doctor available for 20,000 people in a rural population, in contrast to one doctor per 700 people in urban areas. In addition, the total supply of nurses and health visitors is respectively only 23 per cent and 7 per cent of the total number of doctors! So, instead of a practical and operational system of village doctors who could, perhaps, take care of such widespread diseases as malaria and cholera, and who could provide at least some benefits to the majority of the population, we now concentrate on investing in those doctors whose medical college training takes at least five years. They generally go on for further specialization and come back after a considerable time, only to discover the obvious fact that they cannot go into the countryside for two reasons—they would be wasted there and would not have the kind of equipment and facilities they need for their advanced type of research or specialization.

Countries like India and Pakistan can learn a good deal about specialization from the early twentieth-century experience of Russia, where the educational curriculum was geared closely to the manpower requirements of the society. People were trained for a particular job. The skills were narrowly defined and, with a fairly small investment and within a short period of time, skilled personnel were produced for the kinds of jobs society had to offer. We shall return to this subject again. The basic point to be made now is that any type of scientific training should be closely related to requirements, and should be planned much in advance and not left to the haphazard workings of the free academic system, as is done at present.

Second is the error of inappropriate applied research. There is much controversy in developing countries about the priority of applied over fundamental research. It has been argued that about 80 per cent of the funds placed at the disposal of various distinguished scientific institutions has actually been devoted to applied research. Perhaps – but what kind of applied research is it?

To draw another illustration from Pakistan (I am choosing all my examples from Pakistan because I think it is safer to offend my own countrymen!), in the last five years about ten times as much money has gone into nuclear research as into other important fields, such as the development of an appropriate technology for the production and manufacture of jute or the exploitation of the large resources of Pakistan's fisheries. Yet these two natural resources earn upward of $300 million of foreign exchange for Pakistan. When we discussed this question of research priority in the Planning Commission, those in charge argued vehemently that nuclear research was the wave of the future, that we could develop many peaceful uses for nuclear energy, and that we would be left behind in the race of modern science and technology unless nuclear research were given adequate funds. Unfortunately, the proponents of nuclear or other types of advanced and fashionable research are far more vocal and better trained than are the proponents of research into such earthy subjects as suitable varieties of crops, fishery resources, or other fields that have a direct bearing on the growth prospects of the country.

The real tragedy is that, whereas these countries can borrow much nuclear research or advances in heart surgery from the Western world, applied research on natural resources is not available from abroad. In fact, to quote just one example, the West is looking for synthetic substitutes for jute, so jute-producing countries (of which Pakistan is the largest) should devote considerable funds to find new uses for jute to broaden the market.

Unfortunately, not only national governments have distorted patterns of research priorities; the rest of the world willingly lends a hand. Recently, Pakistan received substantial assistance from Germany to set up a modern heart clinic. Similarly, the nuclear research program of Pakistan expects about $60 million of aid from abroad. Again, it appears easier to attract funds from aid-giving agencies for the more glamorous research subjects than for down-to-earth projects.

Third, a common fallacious belief among scientists is that the most modern technology is also the most appropriate for their own countries. In the West, shortage of labor and abundance of capital has led naturally to the development of a relatively capital-intensive technology. In India and Pakistan, with their current population problems, a labor-intensive technology is needed, and numerous adaptations must be made in imported technologies before they can be regarded as appropriate for our economic conditions.

There is a crying need for industrial and technological research to adapt imported technology to domestic needs and prices. Nongovernmental interests in the two countries probably will not engage in such research for a long time to come, partly because its benefits extend far beyond any individual enterprise and are in the nature of social service. Therefore, it is incumbent on the government to invest heavily in applied industrial research. In fact, this is the main rationale for setting up Councils of Scientific and Industrial Research in India and Pakistan. Yet, if one analyzes the contributions these agencies have made to the industrialization programs in their countries, one is sorely disappointed.

Recently we formulated an industrial program of over $2 billion for Pakistan's Third Five-Year Plan; not more than one per cent of it is likely to be based on the technological research developed by our Council of Scientific and Industrial Research. This is no criticism of the Council. It may well be that the planners are not making appropriate allocations for the Council and have not yet recognized that they should not quibble about a few million dollars for industrial research when their industrial programs are so ambitious. It may well be that the entire price system is wrong, so that there is no incentive for local adaptations of imported technology while foreign exchange and capital are being grossly underpriced. For whatever reason, the net contribution of indigenous industrial research has been negligible so far.

International specialization in scientific research is well worth pursuing. We have readily accepted the idea of such specialization in commodities, but we fight shy of it in research. We do not attempt to produce in Pakistan all our requirements for automobiles, air conditioners, or heavy machinery; instead we concentrate on certain products in which we have a comparative advantage – cotton cloth, jute manufactures, cement, and fertilizer. Yet, when we come to the frontiers of knowledge, there is a general reluctance to accept the idea of international specialization. We try to build the latest laboratories, import the latest equipment, and devote our best talent to glamorous projects, even though we could obtain the information from other places in the world.

Scientists are fond of making argument for self-sufficiency in all fields of modern research, irrespective of their cost and priority. In this way we have reached the stage at which an underdeveloped country does not consider itself respectable unless it possesses a costly nuclear research center. Would it not be more worthwhile to devote our meager funds to pragmatic research and to send our specialists to such institutions as the International Centre for Theoretical Physics in Trieste? International specialization would prevent a country from having to duplicate facilities available in another, and, perhaps, obtaining poorer results at a much higher cost. Future budgeting for scientific training and research in our poor societies should be done far more carefully than in the past.

In addition to international specialization, we need better national specialization. Currently, there is a strong tendency for national governments to spread institutes of scientific research all over the country, each with similar departments of science and with inadequate equipment and personnel, although the total resources may not be sufficient to man even one such institute. The net result is the dilution of whatever training and research these poor countries can afford. Here is a real opportunity to reform the content of scientific research and training, to give it a sharper focus in the light of the country's own requirements, and to prevent the huge waste from investment in poor-quality education and research.

Here are a few illustrations of the colossal waste involved in the present system of education and training in Pakistan. Eighty-two per cent of the children who enter class one never reach class five; they drop out, and society loses a substantial proportion of its investment in primary education. As we proceed further, the drop-out rate declines but the failure rate rises, and we find that from 30 to 40 per cent of the students in colleges and universities fail to get their degrees. This means that two out of our six universities are, for all practical purposes, not producing at all. There would be a loud outcry in the country if two out of six factories in which society had invested stopped production, but somehow the high failure rate at the university level is tolerated with baffling equanimity and without much worry about faulty economics. To pursue the story further, many university graduates are not gainfully employed, so there is a further waste. It is all very well to complain that less than 2 per cent of the national income in Pakistan is allocated to education and research. Much more dismaying is that society is getting an extremely poor return on even this 2 per cent.

To return to scientific training and research, it should be emphasized again that something is fundamentally wrong with planning and programing. Scientists are not deriving priorities from the basic and overriding growth-rate objectives of their societies. Ideally, an estimate should be made of the kinds of skills the country requires over the long run in various broad categories as well as in certain specific ones. Then a comprehensive manpower plan should be prepared to utilize those skills.

This plan should be tied in with the educational system of the country by relating job specifications to curricula, and technical training programs should be formulated in detail within that framework. This should be done well in advance, because there is a considerable time-lag in producing human skills. Similarly, research priorities should be derived from the growth requirements in agriculture, transport, and industry, and should be aimed at the maximum exploitation of the natural resources of the country. There are many difficulties in this kind of approach, of course, but even if we can make only second- or third-best guesses, they would be preferable to a haphazard development of scientific training and research that is heedless of the costs and benefits to society.

Such an approach might induce doctors to do some research on local diseases, rather than waiting for an Albert Schweitzer to come and do it for them because they are too busy working on heart surgery or other fashionable subjects. It might also prevent countries from allowing their own doctors and engineers to go abroad, while relying heavily on foreign consultants for their immediate requirements. The "curious imbalance" to which I referred at the beginning of this essay is mainly a symptom of the lack of adequate planning.

One of the most difficult problems facing developing countries is to make individual preferences conform to the objectives of national planning. Both India and Pakistan have mixed economies, with considerable emphasis on individual initiative and enterprise, so individuals cannot be directed to choose those areas for research and training which society, in its infinite wisdom, has decided are necessary for its future growth. This problem can be handled in two ways. First, if a manpower plan exists and is given tremendous publicity, particularly in the technical institutes, colleges, and universities, the individual members of the community will be able to see the range of alternatives society has to offer them. They may then be better able to plan their own training and research within a framework in which their economic opportunities have been identified. Second, there is simply no escape from a major change in the salary scales now offered to scientists and technicians. In the last analysis, pay incentives (together with a sense of idealism and national purpose) are the most powerful weapons in the allocation of human resources. If Pakistan persists in offering its specialists only a fraction of the economic opportunities that it offers to its generalists, it is going to have a shortage of good technicians, no matter how much money it devotes to training and research.

The present system of open entry to the educational institutions in India and Pakistan must also be reviewed. Education in these countries is not a right. It is an investment, and society is entitled to choose eligible individuals carefully. There is no point in clinging to the present so-called liberal concept of education, which claims that everyone is entitled to higher education of some sort, be it history or philosophy or physics. Such a concept is an intellectual luxury that poorer countries simply cannot afford. Our societies have the right – in fact, the duty – to plan and regulate the output of educational institutions, to fix appropriate priorities in scientific training and research, and to take all necessary steps to shape the preferences of the individual to the preferences of the society.

Intelligent planning in India and Pakistan today requires a good deal of cooperation between the planners and the ministries of labor and education. We generally find that education is handled by one department, labor by another, and planning by a third, and there is seldom a meeting of minds among them. Labor and education ministries should be merged into one or, rather, a manpower ministry should be created to be responsible for preparing a comprehensive manpower plan and for regulating the quality and quantity of education required under the plan. The education division and the manpower division, which presently exist as separate entities within the planning commissions of India and Pakistan, should be merged and function as one unit. Manpower planning is perhaps the most neglected field in both countries today and, unless enough attention is devoted to it, scientific training and research will always remain deficient and divorced from national requirements.

The funds being devoted to education in general, and to scientific research in particular, are totally inadequate in the two countries, but the scientists can make a better case for larger allocations only if they relate their demands to the short- and long-run growth requirements of the system and do not make futile comparisons with the Western world. Such comparisons prove only that these countries are at an all-round lower level of development; they do not show that one activity is being neglected for another.

If any comparison is to be made, it should be in the light of national growth requirements. A case can and should be made for investment in scientific training and research in South Asia. Until this is done, the scientists will keep complaining that the economists do not recognize the priority of scientific research, while the economists will keep accusing the scientists of wasting investment.

Science, Technology, and Economic Development: Science Policy and Science Aid

C. H. G. OLDHAM

ALTHOUGH THE MAIN PURPOSE of this paper is to discuss the roles of science and technology in economic development, it is important to stress that they also play important roles in other aspects of development. For example, science and scientific thought undoubtedly play a large part in the social transformation of a traditional, closed society to a modern, open one. The traditional society, with its great respect for authoritarianism and its acceptance of revealed knowledge, is seriously handicapped in its efforts to become modern. The Chinese have been quick to realize this and are making great efforts to introduce science to the Chinese people so that "they learn that the laws of nature can be understood by man, *and* that man can use this knowledge for his own ends."[1]

The direct contribution of investments in science to economic growth is difficult to measure, and although several attempts have been made to do it theoretically, none has been entirely satisfactory. Thus, there is no theoretical framework that can guide developing countries on how to invest in science to maximize economic growth. All countries must, however, base their decisions on allocation of resources on some criteria, and Organization for Economic Cooperation and Development (OECD) pilot teams on science and technology have been carrying out studies aimed at providing pragmatic approaches in a number of OECD member countries.

[1] Comment made to the author by the Director of a Peking Commune in November, 1964.

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These pilot teams are composed of scientists, economists, and engineers – all nationals of the countries in which they work. For several years groups have been operating in such OECD countries as Turkey, Greece, Italy, Spain, and Ireland. Portugal and Yugoslavia have recently set up their own pilot teams. The aim of the teams is to provide guidelines for a science policy that will relate their country's investments in science and technology more closely to their nation's economic and social goals. I will not review the work in detail but, drawing on their experience and that of other countries which have tried similar experiments, I can suggest certain general guidelines that may be helpful.

In the first place, a survey should be made of existing resources of scientific and technical manpower, together with the facilities available for research. Such a survey would result in a collection of statistics on manpower and expenditures in the different types of scientific activities in which the country is engaged. Most statistical surveys of science in the more advanced countries measure only research and development expenditures. In developing countries, it is important to collect statistics on all scientific and technical activities, because it is likely that the scientific extension and information services will be most important in the earliest stages of development. The survey should also attempt to evaluate the quality of the scientific activities and assess their relevance to development.

The second task is to assess the research needs of the country. This is done by studying the economy, sector by sector and branch by branch, to try to assess the areas in which technological changes would make the greatest contribution to economic growth. This phase of the program results in a list of priority areas in need of technological change.

Third, it is necessary to determine the most appropriate technologies for the particular situation in any given country. This is extremely difficult, and involves consideration of many factors, only some of which are technical.

Once an appropriate technology has been defined, it must be decided whether a technology already exists which, with some modification, can be adapted to local use, or whether it is necessary to undertake domestic research and development. It is well to stress that, in the majority of cases, technologies are usually available from abroad, but further research and development are frequently required to adapt them to local conditions. On a few occasions, no appropriate technology will be available and domestic research will be required.

Just as in determining the most appropriate technology, a number of factors must be considered before deciding whether to import or to develop indigenously. These factors include knowledge of available technologies; availability of foreign exchange; possible restrictive clauses of licensing agreements, which prohibit export of goods manufactured from imported technologies; and the need to make fullest use of local raw materials, which may not fit the requirements of the imported technology. Other considerations are the need to encourage an indigenous problem-solving capability in the developing country and, conversely, to recognize that the ability to absorb science and technology depends on a society's own capacity for such research and development.

Then follows an analysis of the ways in which existing resources of manpower and facilities, as determined in the initial survey, can be matched with those requirements for research and development that are subsequently identified. Usually the gap between available input and requirements will be found to be large. The next step is to formulate policies to help close this gap. These policies will affect the higher education system and its ability to produce additional manpower of the right quality and in the right numbers. They will also affect the organization of science and technology, from the infrastructure for research with all its supporting activities to the best ways for organizing extension services in agriculture and industry.

The final stage consists of putting into effect all the recommendations and policies formulated in the earlier stages. It also requires a continuing reappraisal to make sure that the work is related to development objectives.

There are, of course, many factors of a nonscientific nature that make it extremely difficult to carry out the logical sequence of analysis described here. However, the guidelines provide a useful framework in which to formulate scientific and technological policies that relate science and technology to development.

In implementing these policies, an important potential lies in the type of scientific assistance the more advanced countries can give to the developing countries. A good deal of work and thought has been given to this, especially by the United Nations, but it is useful to summarize briefly those aspects for which aid is frequently required. For the most part, only areas and problems will be identified; the aid implications are obvious.

The problems associated with the transfer of scientific knowledge are common to all countries, but are complicated in developing countries by three factors. First is the language problem. In general, the languages spoken by the majority of people in developing countries are not those in common usage for the communication of scientific results. Second, scientists in developing countries are isolated. It has been estimated that, in an advanced country, the inputs – in terms of scientific knowledge – for a particular piece of research derived from published information amount to only 20 per cent. The remaining 80 per cent comes from personal contacts and knowledge of what is going on elsewhere. This is communicated by private letters, by privately circulated papers, or by meeting other scientists at conferences and symposiums. Many scientists in developing countries are cut off from much of this interchange. Third – and related to the first two points – is the shortage of money for scientists in developing countries to attend international scientific conferences and to subscribe to journals.

The problems of transfer of technology are different from those of the transfer of science. Only a relatively small part of the transfer can come from books or journals. Like learning to fly or swim, technology can only be absorbed or learned by doing. One of the most frequent ways in which technology is transferred is by the licensing agreements between the producer of the technical know-how in an advanced country and the user in a developing country, but there are at least two important problems. First is the lack of knowledge on the part of the potential purchaser about the most appropriate technology for his needs. Second is the developing country's lack of foreign exchange to pay the licensing fees. There is need for much greater study of the ways in which developing countries can be helped to acquire more of the technologies available in the world. A strong case can be made for an international technology agency that might act as a broker between enterprises in developing and developed countries.

There appears to be a growing desire among many scientists in the more advanced countries to help solve these problems. Ideally, some scientists could assist by spending a period of time in the developing countries. For many, this is not possible. They could, however, contribute by carrying out research on problems that have special importance to developing countries. The Advisory Committee to the United Nations Economic and Social Council on the Application of Science and Technology to Development[2] has identified twenty-seven such research areas, and called for a concerted attack by the scientists of the world. At the present time, only about one per cent of the money spent on civilian research and development is devoted to areas of special relevance to developing countries. This amount could be considerably increased, and the results would provide a long-term form of science aid.

The reasons developing countries need their own indigenous scientific and technological infrastructure have been discussed in other papers in this volume. The scale, timing, and rate of scientific growth varies from country to country, depending on its size, stage of development, and other historical, social, and political factors. No general rules can be laid down to govern the way in which a developing country should establish its own science. Nevertheless, the following factors are among those that must be consid-

[2] United Nations Economic and Social Council, Official Records, 39th Session, Supplement 14 (May, 1965).

ered. Help in establishing each of them would be a valuable form of science aid.

One of the first requirements is the creation of a council to determine science policies and priorities. It is sometimes argued that developing countries have so little science they do not need a science policy. On the contrary, their resources in money and manpower are so sparse that it is especially important to see that they are allocated wisely to projects relating to development objectives. The *ad hoc* growth of scientific activities, such as has occurred in the past in many countries, is too great a luxury.

Education and training of scientific manpower of the right quality and in the right quantity to meet the needs of the country is another obvious necessity, as is establishment of the organizational complex of science. The latter includes research institutes, survey units, and standards, testing, and documentation services.

A vital and pervasive need is the creation of a hospitable environment for science. To do good research it is not sufficient to have scientists and laboratories. A third, almost indefinable, factor also seems essential. This is the scientific environment. Some of the elements that contribute to this rather nebulous requisite are the attitudes of government and the mass of the population toward science, the attitude of scientists toward their own work, the significance of scientific tradition, and research management.

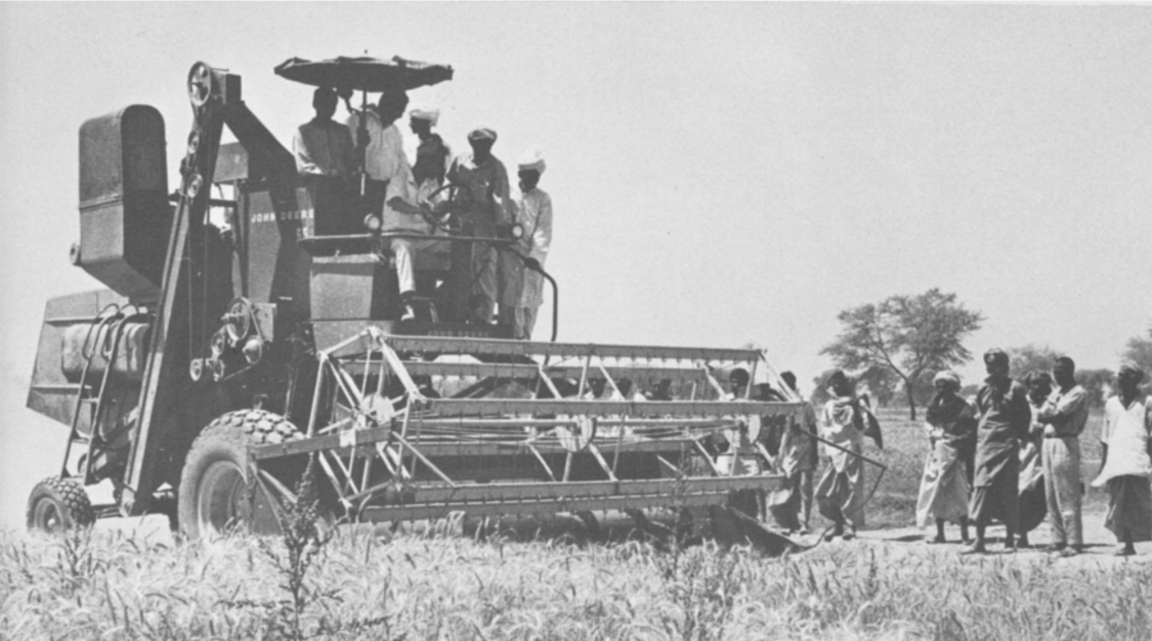
Each of these factors should be analyzed to determine the specific ways in which they might contribute to the establishment of indigenous scientific activities in a particular country. On the basis of this analysis, the most appropriate forms of science aid could be determined. Such aid, wisely conceived and carefully administered, could be a vital element in furthering economic and social growth in developing societies.[3]

[3] The views expressed in this essay are based on a combination of visits to several developing countries in Asia, together with a year spent with a group working on the problems of science and development at the Organization for Economic Cooperation and Development (OECD). I wish to acknowledge the contributions made by my colleagues at OECD, but stress that this essay presents my own views and not official OECD policy.

A Pakistani winnows wheat in age-old way. At Comilla Academy in East Pakistan, Michigan State University men under Ford Foundation auspices train farmers in harvesting with a combine to increase the agricultural yield.

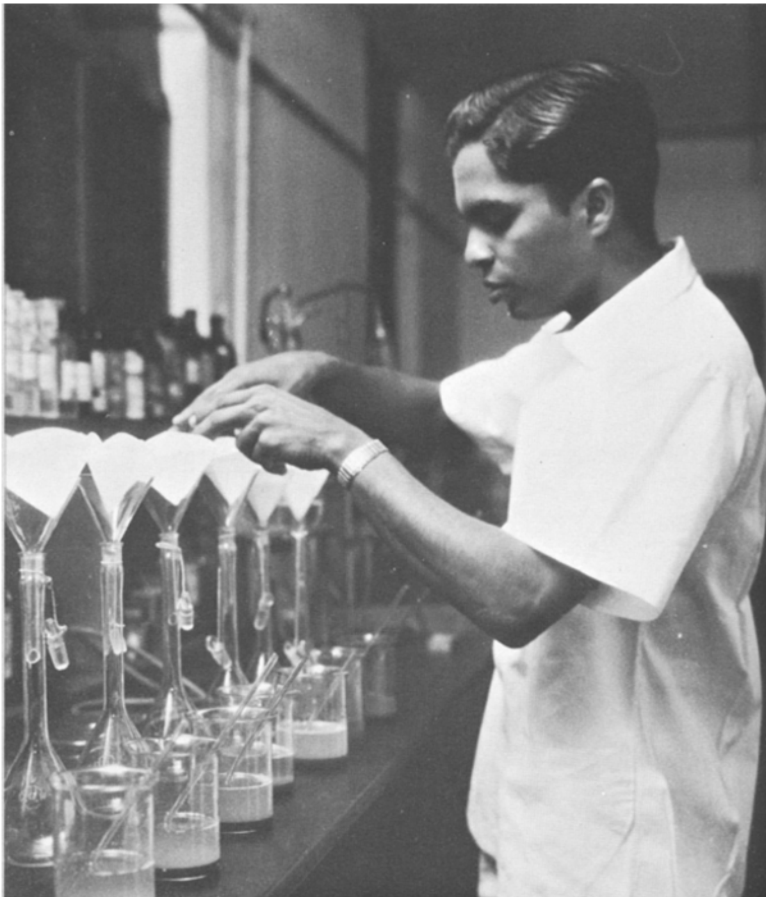
MONKMEYER / FUJIHIRA

FORD FOUNDATION / FRED WARD



Fishermen seine for fish off a beach near Calcutta. India's fish protein intake remains, however, much too low.

GOVERNMENT OF INDIA TOURIST OFFICE



Technician studies fish-oil samples in laboratory of Central Institute of Fishing Technology, Cochin.

UNITED NATIONS

Agriculture student at Gandhigram learns way of plowing with ancient plowshare and bullocks.

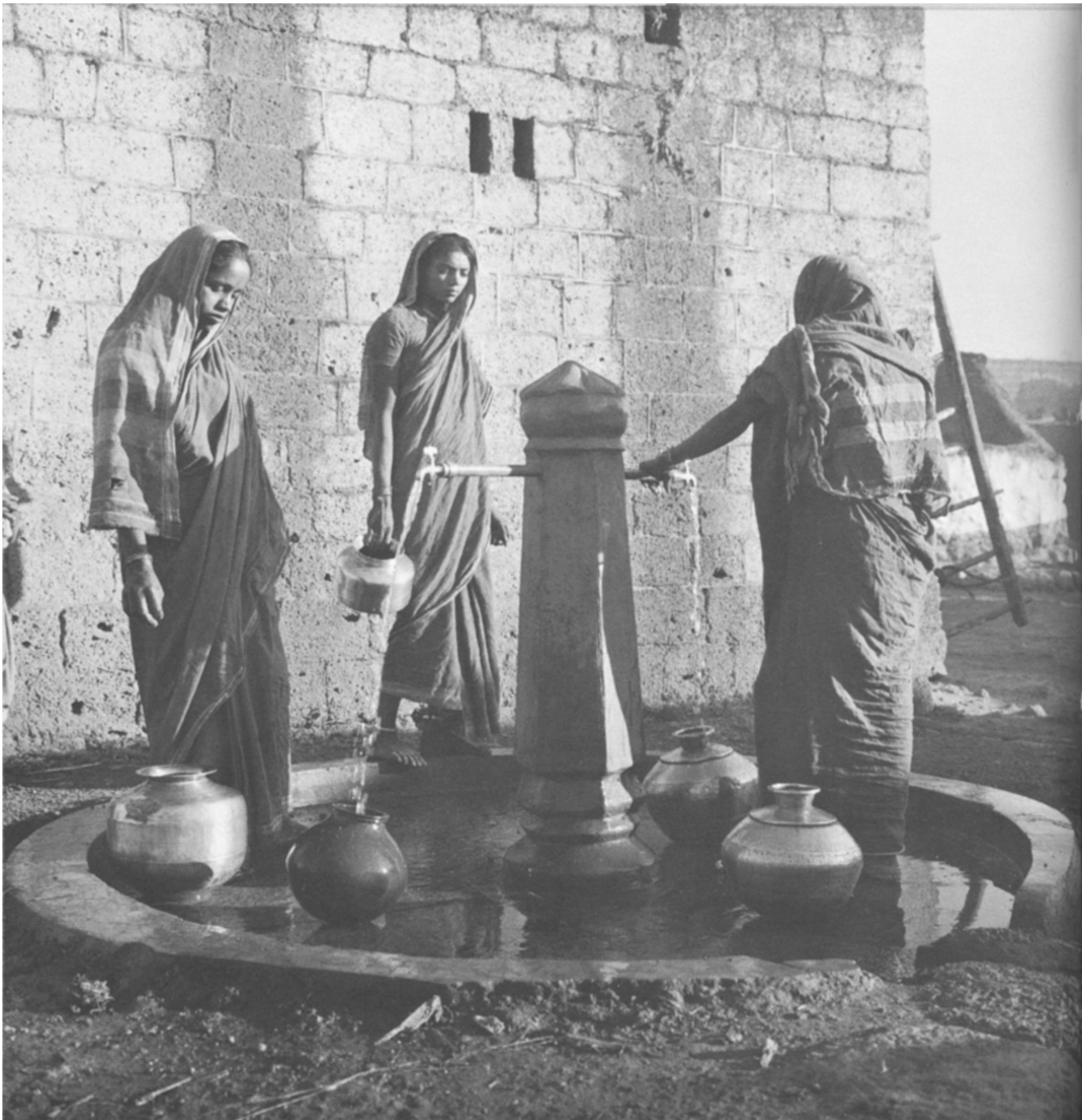
FORD FOUNDATION / HOMER PAGE

A high stand of maize was produced by using modern methods at the Deochanda Experimental Farm, India.

GOVERNMENT OF INDIA TOURIST OFFICE

Water—its abundance or lack—is a constant problem for the subcontinent. Indian women draw water from a tap, below, that replaced the village well. Tilaiya Dam, right, has helped to irrigate portions of Bengal. Below, women laborers in south India pass up baskets loaded with rock and dirt from men digging a well. Thirty itinerant workers are able to dig a well 40 feet deep and 20 x 20 feet square in approximately thirty days.

FORD FOUNDATION / WILLIAM SIMMONS



GOVERNMENT OF INDIA TOURIST OFFICE

FORD FOUNDATION / ERNEST KLEINBERG

MAGNUM / MARILYN SILVERSTONE

Doctor, above, conducts a birth control clinic in India. In Madras, a visiting health nurse from the Tuberculosis Chemotherapy Center consults with some of her patients, below.

UNITED NATIONS

MAGNUM / MARILYN SILVERSTONE

Ayurvedic medical men treat patient with warm oil, above, to cure nervousness. Some of India's trained doctor corps, below, based in cities, travel to care for villagers.

MAGNUM / MARILYN SILVERSTONE

MAGNUM / RENÉ BURRI

Aerial view of salt deposits on land, above, dramatizes Pakistan's agriculture problem. Irrigation and other programs allow crops like sugar cane to grow. Oxen operate grinder, below.

UNITED NATIONS

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POPULATION, NATURAL RESOURCES, AND HUMAN WELFARE

Human and Natural Resources: Interaction and Development in India and Pakistan

ROGER REVELLE

THE MOST SIGNIFICANT statement that can be made about the human resources of India and Pakistan is also the most obvious: there are a great many people. One out of every five human beings in the world lives in the Indian subcontinent. Within a few decades there will be 1,200 million Indians and Pakistanis. Inordinately high rates of population increase can seriously inhibit economic and social development in several ways. In India and Pakistan, where populations are doubling each generation, 42 to 47 per cent of the people are less than fifteen years old. This means that nearly one out of every two people in these countries is a dependent child who must be fed, clothed, and taken care of by the adults, who are a bare majority of the population. As a result, most of the energy and time of the adults must be devoted to keeping themselves and their children alive. A relatively large part of the national income, which might otherwise go into short-term investment, must be spent on health and welfare services and on education. Although these are undoubtedly sound long-term investments, they will not show real economic benefits for 15 to 20 years. In the meantime, they reduce current funds available for fertilizer plants, sugar mills, textile factories, paper mills, and other instruments of production that have short-term pay-offs but can contribute immeasurably to the long-term welfare of the people.

A rapid rate of population growth also means that per capita income rises slowly, particularly if the total national income is not rising rapidly. As a result, it is hard to increase the fraction of income going into savings

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and, under the right circumstances, into investments. In India, per capita incomes are approximately $70 a year (less than 20 cents a day), and recent levels of annual increase are less than 2 per cent. An Indian who receives $70 this year will get $71.40 next year. This slow rate of increase, not surprisingly, stultifies incentive.

No reduction in birth rates during the next fifteen or twenty years can have much effect on population size or on the requirements for resources to keep people alive, clothe, feed, and house them, and give them the possibility of living in human dignity. Even if the Indian birth rate goes down by more than 50 per cent over the next 30 years – from about 40 per thousand to about 19, which is roughly the United States birth rate – the difference in population size in 1980 would be only 10 per cent less than if the increase continued at its present rate. Although reducing birth rates will eventually help to solve economic and social problems, increasing food supplies and productivity are of equal concern for the short term.

In West Pakistan, increases in agricultural production may soon be sufficient to feed the population, but in India and East Pakistan, the need to increase food supplies has a tragic urgency. I refer here to agriculture in its broadest sense – the utilization for human welfare of the living resources of the land and the surrounding ocean.

First, India should ensure a minimum diet for all its citizens. Such a diet is, by any reasonable definition, not now available. In recent years, perhaps a quarter of the people in India have obtained fewer than 1,800 calories a day – not really enough to live on. Second, the amount of high-quality protein – which means protein that contains the right balance of amino acids – must be increased. A protein deficiency in the diets of children results in physical, and perhaps mental, retardation. Third, a continuing increase in yields per acre and in total food production should be set in motion at a rate significantly higher than the rate of population increase. Fourth, dependence of the nation's food supplies on the vagaries of the monsoons and the winter rains should be lessened and, if possible, removed. Fifth, the living conditions of the rural population should be improved (this sometimes goes under the euphemistic name of "community development"). Finally, the products of farms, forests, and fisheries should be diversified and improved to increase the proportion of cash crops, raise the quality and variety of human diets, lift export earnings, and provide a wide range of improved raw materials for industry – leather, wool, cotton, silk, rubber, timber, paper, and cellulose. To accomplish these objectives, large-scale capital investment and a great deal of skilled human effort are needed.

During the 15 years from 1950–51 to 1964–65, agricultural production in India rose by about $5 billion – from a value of approximately $10 billion a year to around $15 billion. This was an average annual increase rate of nearly 3 per cent. But even before the disastrous years of crop failure in 1966 and 1967, the production increase rate had been steadily declining. From 1960–61 to 1964–65, production of food grains – principally rice, wheat, corn, millet, sorghum, and pulses, which provide 76 per cent of the calories in the average Indian diet – increased by a smaller percentage than did the human population. Because of agricultural stagnation and the accelerating population increase, per capita incomes were rising at an ever slower rate – probably less than 2 per cent per year from 1960–61 to 1964–65.

To double Indian food production during the next fifteen years will require a capital investment equivalent to about $25 billion. This amount is needed for many things, the most expensive of which will be the development of surface and underground water. Fertilizer, better seeds, and better agricultural practices cannot be used effectively unless water is available at the right time and place. However, no single input will suffice; everything is needed.

In addition to capital investment, India needs skilled people. At the present time, one out of every thousand agricultural workers has had three or more years of college. He is a college graduate, in the Indian sense. Three out of a thousand have gone through two years of high school. Ten thousand people hold professional agricultural degrees. About 300,000 specialists trained in a profession, 30 times as many as there are today, will be needed by the end of the next 15-year period. Somewhat less than half of these should be agriculturalists.

Not only agronomy, veterinary medicine, and soil science, but a variety of other professions must contribute to agricultural development. I have convinced myself, after giving it considerable thought while a member of the Education Commission of the Government of India, that there is one "best" way to educate the specialists who are needed and to keep them working well. India should establish at least 20 agricultural universities that would correspond to the land-grant colleges of the United States – not as they are today, but as they were in the nineteenth century. I am not proposing that India reproduce the modern universities of California or Illinois, but rather that it try to create Indian institutions something like the University of California and the University of Illinois when their primary objectives were agricultural and related developments in their own regions. At that time they were concerned with all aspects of increasing, disseminating, and applying knowledge related to agriculture, including basic and applied research, teaching students, and transmitting needed information to farmers through extension services and publications.

They also emphasized teaching and research that were directly and immediately related to the solution of the social and economic problems of the state in which they were located. The colleges were ready to teach undergraduates, postgraduates, and research students, and to give specialized technical training to young people who were not candidates for degrees – that is, to give what in India and Pakistan is now called polytechnic training. They offered adult and continuing education side-by-side with that for regularly enrolled students.

Many people from Ivy League universities ridiculed their curricula because they included such unacademic subjects as home economics. Yet these colleges were precisely what was needed at the time to build a rural economy. They are also what India and Pakistan need today.

The present university system in India has arisen to meet some of the needs of a rural society. Most of the people live in villages or small towns, and education at all levels must be adapted to their geographical distribution. Under the circumstances, it is extremely difficult to build more than a few large metropolitan universities. Instead, there are 2,000 small colleges scattered across the countryside. They are too poor and too small to have more than rudimentary libraries, limited laboratory facilities, and insufficient faculties. As a result, teaching consists largely of cramming the students for an external examination – the opposite of the kind of teaching needed to create a modern spirit.

The new agricultural universities in India and Pakistan should teach the classical agricultural specialties – agronomy, plant genetics, animal breeding, animal husbandry, veterinary sciences, plant pathology, soil science, microbiology, horticulture, entomology, and parasitology. They should also teach engineering for agriculture, including irrigation engineering, ground-water hydraulics, civil engineering for the design, construction, and operation of surface-water supply systems, and mechanical engineering concerned not only with farm machinery and equipment, but also with well-pumps, motors, and strainers for ground-water development. One of the worst failures has resulted from the lack of appreciation of the water and drainage requirements of plants and soils on the part of engineers in charge of water development. The average engineer does not seem to consider the average farmer's needs; he believes it is enough if water is supplied when it is most convenient in terms of operating the irrigation system. This attitude has prevented the use of irrigation water to maximum advantage. To use it well, farmers and engineers should cooperate closely; this will be possible only if the agricultural universities take the responsibility for producing a new breed of engineers.

Specialists in human nutrition and food technology are also needed. Food wastage could be lowered by better methods of preservation. Even with present inadequate food supplies, the diets of the poor could be improved and deaths of many children prevented if inexpensive, high-quality protein supplements could be made available in an acceptable form. Knowledge of nutritional requirements and how to meet them must be widely disseminated among the rural people. The leading causes of death in India are not cancer and heart ailments, but infant diarrhea and other childhood diseases that are greatly aggravated by poor nutrition.

Agricultural economists are needed for market research, data compilation and analysis, farm management, rural credit, crop insurance, benefit-cost analysis and other techniques of project evaluation, and for determination of price structures for farm products. Public administrators are needed, particularly specialists in the organization of governmental agricultural services, management of cooperatives, local self-government, and relations between different governmental levels. Mass communicators, who can find ways to reach illiterate people, are also necessary. Anthropologists, sociologists, and lawyers must be concerned with land reform and land consolidation. Specialists in soil conservation are a vital part of the future; a considerable fraction of India's 320 million cultivated acres has deteriorated through misuse, and urgently requires treatment. Foresters and fishery specialists are needed to help increase the harvests from the forests and the seas, as are meteorologists and oceanographers to learn how to forecast the monsoons.

Finally, the agricultural universities need basic scientists and humanists. Their students should have a background of Indian history and literature if they are to understand the traditions and values of rural society and the attitudes, uncertainties, motivations, and fears of the farmers. The villagers have been oppressed by the government for 2,500 years, and they have developed a defense in depth. When the census-taker comes around, they will not even tell him their ages; they let him make a guess.

Farming has a low social status on the subcontinent, as is now true in many places in the world. It is nearly impossible to persuade a village boy who has managed to obtain a higher education to go back and work in his village. Consequently, the most difficult tasks of the agricultural universities will be to select and recruit able young people and to give them not only the necessary intellectual and practical skills but also the desire and the will to work in rural areas. The effectiveness of these universities will depend upon their ability to compete with other professions by providing their staffs with adequate incomes, life-time careers, and a total environment. It may be desirable for many staff members to rotate assignments among classroom teaching, laboratory research, experiment station research, and field work with rural people.

With only 10,000 persons holding advanced agricultural degrees at present, how can the required numbers be educated during the next fifteen years? It is manifestly impossible with India's own resources. Here is a clear-cut case of the need for specialists from the rich countries – Americans, Canadians, Australians, Europeans, and Japanese – to go to India to help the agricultural universities get under way. It will be equally necessary for those countries to take Indian and Pakistani students into their universities and experiment stations and teach them how to be teachers, researchers, and field-workers. Our agricultural colleges have helped to create the astonishing agricultural revolution in the United States; they have been so successful they have almost worked themselves out of a job. Here is a tremendous new task for them.

One aspect of the over-all development of natural resources is often given insufficient consideration. A great deal of work goes into surveying land, water, and minerals, and much planning and programing are done for investment, but usually a country's problems and the probable consequences of different lines of attack are insufficiently analyzed. The first step of such an analysis should be an effort to formulate the real problems. An example is the Indus Plain of West Pakistan. Here waterlogging and salt accumulation in the soil have made large areas unfit for cultivation. The effects are striking and tragic; as one flies over the country one sees great white patches of salt on the surface, and many abandoned farms. At first it was thought that reclamation of the deteriorated land would solve the problem. Analysis showed, however, that the good or only slightly deteriorated land remaining could use all the available irrigation water. It was more important to concentrate first on developing new water supplies – particularly the ground water that lies in a vast lake under the Plain – and to combine this water development with the introduction of other inputs needed for increased agricultural production, including chemical fertilizers, pesticides, improved seeds, and better agricultural practices. The real problems were largely social and economic, not physical. A massive attack on a broad technical, economic, and educational front was called for, and is, in fact, being made today. The farmers are proving to be surprisingly enterprising. They are quite willing to change their traditional ways as soon as they can see a profit in so-doing. Agricultural production in West Pakistan is now going up by 5 per cent a year, corresponding to a 100 per cent increase in 15 years. This is a remarkably rapid rate of improvement, compared to the agricultural stagnation over much of South Asia. It is one of the success stories of development.

A similar opportunity for great change exists on the other side of the subcontinent, in the lower basin of the Ganges and Brahmaputra rivers. These are among the greatest rivers on earth. The combined flow of the Ganges and Brahmaputra is exceeded in volume only by the Amazon; about a billion acre feet of water run to the sea every year, primarily during the monsoon season. In the countryside fed by these rivers, 175 million people live in abject poverty. Some 65 million are Pakistanis, about 110 million are Indians in Bihar, West Bengal, and Assam. Their per capita incomes are, on the average, a good deal less than those of the subcontinent as a whole – probably around $45 to $50 a year. They depend largely on one crop – rice grown during the monsoon season, when the rivers are in flood. During the other eight months of the year, much of the land is fallow and most of the people are idle. There simply is not enough water to grow a crop, except in some areas where a little rain, together with moisture remaining in the soil, allows a second crop to be grown during fall and winter, and a few places where there is rain during most of the year.

Development of surface and underground water resources would make it possible to grow crops throughout the year. Surface or underground reservoirs to store water until it is needed, canals and conveyance channels, wells, and motor-driven pumps must be built or installed. In many areas, three crops could be grown each year. With water available at the right time and in the right amounts, chemical fertilizers, higher-yielding seeds, pest control, and improved agricultural practices could be used economically to triple crop yields per acre. Combined with multiple cropping, this could more than quadruple food production. The difficulty is that within a few decades it will be impossible to farm the land efficiently because there will be too many people, unless urbanization and industrialization can be accomplished on an unprecedented scale.

At present rates of population growth, there will be something like 450 million people in the basin of the two rivers by the end of this century. This is more than twice the present population of the United States in an area one-fifteenth as large. Today, most of the people are rural, and most of the labor force are farmers. Some 25 million persons live in cities and towns, including the great city of Calcutta and the industrial complex of Bihar. If population increase continues unchanged until the year 2000, there will be nearly 300 million nonfarmers instead of the present 25 million. Existing cities and towns must be vastly enlarged and new cities built to accommodate them. Somehow in the next three decades ways must be found to provide nonagricultural jobs for 75 million workers – approximately the entire present labor force of the United States.

An international cooperative project is essential for the necessary river-basin development. Probably close to $40 billion should be spent for irrigation and flood control alone. To produce jobs for 75 million workers outside of agriculture may cost another $200 billion. Thus, the total cost of the project over the long run would be the equivalent of a third of the yearly gross national product of the United States. Although other countries can help, most of the effort and investment must be undertaken by India and Pakistan, but the task can be accomplished only if the two countries work together. Here is a challenge that could absorb the energies and the enthusiasms of the two peoples and might be a substitute for some of their hostility. In several years, the task of developing the Ganges-Brahmaputra river basins would resemble the work of the Tennessee Valley Authority in the United States, but on a scale fiftyfold greater. In terms of magnitude, it would be the greatest single project undertaken in human history.

A birth-rate reduction would, of course, make things easier. For example, if the birth rate could be halved during the next 35 years, the total urban population would be 170 million instead of nearly 300 million. Assuming the objective is to raise per capita income to $200 a year by the year 2000, the high rate of population growth would mean a necessary tenfold increase in regional income – from about $9 billion at present to $90 billion. However, a low rate of population growth would require a regional income of only $65 billion – a 40 per cent smaller increase above present levels.

What possible kind of economic development will increase incomes between seven and ten times in the next 35 years? Clearly, there must be much more than agricultural development, if for no other reason than to give farmers a market for their crops so they can, in turn, buy water, fertilizer, and other factors of increased production. What other resources are there? There is natural gas in East Pakistan and potential hydroelectric power in the upper reaches of the river basin. Coal and minerals occur in Bihar, and oil in Assam. Further harbor development is possible in Calcutta and in Chittagong, and in the Dacca area of East Pakistan. The Ganges and its tributaries could be developed as a great navigational highway into north India. Forests can supply raw materials for paper, plastics, and plywood. Above all, there are the people, who need only a chance to use their energies and develop their abilities.

The extreme poverty of the two countries is obviously a serious road block to education in India and in Pakistan. These are not primitive societies. They are highly developed, ancient, and proud civilizations, but today they are among the most deeply impoverished countries that have ever existed. Each year the United States spends more on education than the entire gross national product of India; yet in India there are more than three times as many children to educate. Pressures for the bare necessities of life are so great that India is able to spend only about 2 per cent of its national income – about $800 million a year – on education. This corresponds to $4 a child, compared to the $500 to $700 per child in the United States. If we assume that all children in the five- to fourteen-year age group are in primary schools, with one teacher for every 40 students, and take 75 per cent of the educational budget for salaries of primary school teachers, the average teacher would be paid only $120 a year. If he had a wife and one or two children – as he almost always would have – his salary would not be equal to the per capita income of his fellow Indians. It is virtually impossible to get teachers to work for $120 a year; as a result, some Indian children never see a classroom. Of those who do, many do not stay long enough to become functionally literate.

Yet great strides have been made in the last few years; 60 per cent of the children between six and eleven years old are now in school. This is a remarkable improvement over the situation even ten years ago, when the figure was only about 10 per cent. However, without an increase in either the national income or the proportion spent on education, it is going to be hard to do much better.

A second difficulty, at least in India, is the traditional authoritarian, stratified nature of society and the high status given to government administrators. The educational result is an emphasis on rote learning and on producing generalists rather than professional specialists. J. P. Naik, the member-secretary of the Education Commission of the government of India, has said that there are three things wrong with Indian education: "(a) It is inappropriate; (b) it is inadequate; and (c) it is no good." In higher education, many of the students do not like to study and many of the teachers do not like to teach. The Commission visited a number of universities in India, and in each case we attempted to talk privately to the twelve brightest students. I always asked them this question: "How many of you would like to be a university teacher?" I never found one who did. If the same question were asked in a good American university, 75 to 80 per cent of the brightest students might say they wanted a career in university teaching and/or research.

Typically, Indian college and university students spend up to 35 hours a week in class, and the young teachers up to 25 hours. Of course, it is impossible to teach 25 hours a week at the college level, so the teachers dictate their notes and the students simply copy them. On the surface, this would appear easy to change. However, the necessary keys are good, open, well-arranged libraries and, if possible, laboratory facilities and other means whereby the students can study independently. (Even textbooks are scarce in most Indian colleges.)

India and Pakistan are not alone in their education problems. The same kinds are faced by nearly all the less-developed countries and are important fields for applied science and technology. Many types of educational research and experimentation are needed – on curriculum improvement, on ways to achieve a quantum jump in teaching effectiveness, on training enough good teachers, on educational administration and organization, on national needs for educated manpower. The typical economic approach in determining the kinds and numbers of people who should be educated is to depend on projected trends, but education changes directions. Ashoka Mehta, in a speech given to the Education Commission of India, stated the underlying educational problem of our times in a single eloquent sentence. "In former days, the teacher could provide the students with a map to guide them through life; now the best thing he can give them is a compass."

In the midst of the scientific revolution, few of the so-called facts one learns in school are useful or even true ten years later. Consequently, one essential aim of modern teaching should be to give the student an enduring knowledge of the fundamental principles and language of each subject to enable him to solve new problems as they arise. It is equally essential to instill in him a continuing interest in learning.

The most far-reaching of all the social changes so inexorably demanded by the modern world is a change in the methods, scope, objectives, and importance given to education. This is most clearly needed in the less-developed countries but, in fact, is needed everywhere. Within our own generation, education of many different kinds, at many different levels, for human beings at all stages of life and from all over the world, may well become the central activity of the people of the United States.

The new education can best be described by comparing its goals—the goals of education in a world of change—with the goals of traditional education. The new education strives to give problem-solving ability; the old leads to rote learning. The new seeks to instill a belief in experimentation and empiricism and to bring about a love of innovation; the old asks acceptance of authority and tradition. The new emphasizes creativity, self-confidence, and optimism; the old requires regimentation, fatalism, and the search for security. The new seeks to build interest in and the ability to continue learning throughout life; the old offers only the terminal education characteristic of poor countries.

If economic and social development are to take place, education also must lead to a sense of public morality and responsibility. Because traditional education is shaped to a traditional society, it teaches responsibility only to family, caste, or class, and not to society as a whole. Finally, modern education, unlike traditional, should emphasize ingenuity, inventiveness, the ability to manage and to make decisions.

We have discussed the need for establishing first-rate agricultural universities. An equally valid justification can be given for establishing several outstanding institutes of technology. If India and Pakistan are to take their proper places in the modern world, they must also develop some broadly-based universities that are comparable, both in the caliber of their students and the fame of their professors, to those in Moscow, Tokyo, Cambridge, or Berkeley. A few departments in a few Indian universities already meet these exacting standards. Any country in the world would be proud to contain the Department of Economics of Delhi University or the Tata Institute in Bombay. A university gains strength from being a community of scholars. If it is strong in several different disciplines, the faculty members can support each other in teaching and research. In spite of poverty, population dispersion, and traditionalism, India and Pakistan must develop a few great general universities during the next twenty years.

What would undergraduate education in such great universities be like? In the first place, a complete reform of teaching methods would be possible, based on highly competent faculties. No committee would prepare the syllabus for any course. All examinations would be given by the class instructor, because he would know best what his students should have learned from what he had been teaching. There would be no distinction between undergraduate and postgraduate teachers. Senior professors would give lectures and preceptorials for beginning students to start them off as soon as possible in the disciplines of true scholarship. (This is already done in the B.SC. honors courses at Panjab University.) Much of the postgraduate and research teaching would be given by lecturers in special fields. Some undergraduate teaching would be handled by research and senior postgraduate students. B.A. and B.SC. candidates would be started on small research problems as soon as possible – not necessarily original research, but on the analysis of data and the synthesis of ideas needed to answer specific questions. There would be high admission standards for the students, but once they were admitted, every attempt would be made to keep them in the university until they received their degrees. Students would spend not more than ten hours per week in lecture classes and three hours in the laboratory. Those in the humanities and the social sciences would spend most of their time in independent study of assigned reading and in essay writing based on that reading, and most vacation periods would be spent in reading related to their studies. Much study time of students in scientific and technical subjects would be devoted to solving problems.

No faculty member would have more than nine to twelve formal "contact hours" with undergraduate or postgraduate students, and all faculty members would be involved in research or other forms of scholarship. Their academic careers would depend largely on their accomplishments in these fields. When appropriate, consulting work for industry or government would be given equal weight with other kinds of research or creative activity.

These outstanding universities should be located near large cities. They would have several hundred acres of land on which to build their campuses. They should either be unitary universities or be made up of constituent colleges located entirely on the central campus. Their hostel facilities should be sufficient to house at least those students whose homes are outside the city in which the university is located.

Today we are concerned with the greatest force that has ever existed in the long history of the human species – the dynamic force of science. This is too often taken for granted and too often misunderstood. During the last 300 years greater changes have occurred in the life of man than in the entire thousand millenia of his previous existence; his new-found ability to control his environment and to work with it has literally revolutionized the world. We cannot predict the future in any satisfactory way, but we can be fairly certain that, under the impact of science, far greater changes will occur in the next 100 years than took place during the past 300. I believe we can face this future with courage and optimism. Science itself is essentially optimistic. That is why it is needed in all countries and particularly in the developing countries – not because of the advantages, physical or mechanical, that it can produce, but because of its spirit of rationality and optimism, its faith that men can understand the world and themselves, its belief that changes in the human condition can occur and that these changes can be guided by human beings, and its demonstration that there is a real unity of human thought – that men are truly a band of brothers.

The Health Sciences and Indian Village Culture

CARL E. TAYLOR

THE SUBJECT OF medicine and public health in India is so large that I will concentrate on the impact of health sciences on Indian village culture and will make no attempt to discuss the excellent laboratory or clinical research carried on in that country.

The health sciences contribute more directly and more profoundly to change and innovation in traditional societies than do almost any other aggregations of scientific disciplines. The only possible exceptions are those involved in transport, communication, and agriculture. The impact of health sciences on traditional agrarian societies occurs as a result of six direct effects.

First, there are few matters of which village people think and talk more than about how they feel. Although this is true of most people, villagers also worry a great deal about supernatural and physical forces, which seem to them to contribute to health problems. Any outside ideas that modify these basic concerns necessarily influence a wide range of village thinking. Alteration of beliefs about one's self leads to numerous repercussions in thinking about one's environment.

Second, the health sciences are not only broad in their effect; they also probe deeply into the most fundamental values of traditional society. Much of the superstructure of culture is built on a foundation of deeply grounded beliefs about the things which make people feel well or ill.

Third, adding years of life changes the whole time perspective. When a person can, with some assurance, look forward to old age, there is far more incentive to work and plan for long-range development than when individuals and families are bound to a mere day-to-day struggle for survival. Even more important, when individuals see that their children are

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surviving, rather than falling into the group of more than 50 per cent mortality, planning for the future is immediately extended to the next generation.

Fourth, the technical achievements of health sciences carry a dramatic quality that is directly and immediately convincing. Many therapeutic and preventive techniques produce benefits that are both obvious and surprisingly prompt, as in the 48-hour response of secondary yaws to penicillin, or the few weeks that are necessary for DDT to show an effect on malaria transmission. The magical quality of the transformation in a child with kwashiorkor or marasmus when specifically required food supplements and hydration are provided surrounds the healer with an aura of credibility that carries over into many other fundamental aspects of life.

Fifth, better health has its own immediate and direct positive input in economic development. Whether human resources are improved by health measures does not seem an important issue where health is already above the threshold of effective productivity. Where health conditions are extremely bad, however, there are several measurable benefits of improvement. Among these are greater productivity of workers and greater responsiveness to innovation. Even where seasonal underemployment is a problem, better health provides greater drive for innovation, in that the sick can scarcely be expected to have the initiative to start new enterprises. Furthermore, we are increasingly recognizing the serious developmental damage in sick and malnourished children, which has a negative effect on their adult capacity in a reverse twist on the survivors of natural selection.

Sixth, the most dramatic effect of improved health on rural populations is the problem of numbers. Health has been blamed for population growth because it accelerates the fall in death rate, which would occur anyhow with economic development. Health services also provide the best means of lowering the birthrate, because parents will not limit family size until they are sure that the children they have will survive. The net demographic effect of a strong health emphasis is a favorable one.

Perhaps the most dramatic transformation that has occurred among medical and health scientists of India in the last several years has been the discovery of "the village." Few groups of scientists have been more strongly influenced by Western teaching and Western culture than has the medical profession. Medical education in India was based on the dogma that the early British educators in India were working in a complete vacuum of medical ignorance. British doctors essentially ignored or ridiculed the quackery of indigenous practitioners. Indian doctors often became more British than the British in their insistence on maintaining the standards of Hammersmith and Harley Street.

The cultural response was only natural. In making a break with their own culture and its aggregate of religio-medical beliefs, these doctors found security in accepting the professional culture of Western medicine in toto. As a result, it proved to be hard for Indian doctors to select and adapt those parts of the Western medical culture that were relevant to the country's needs while, at the same time, compensating for feelings of social inferiority imposed on them by the representatives of the British Raj. This generalization is made with due recognition of outstanding exceptions.

Since Independence, Indian medical educators have shown progressively more self-confidence in adapting medical education to national needs. Public health leaders also have been quietly experimenting with various imaginative approaches to meet the needs of rural populations, with many unpublicized efforts in addition to such well-known demonstrations as Tagore's Sriniketan and Gandhi's efforts at Wardha. Built into the famous Bhore Committee report[1] on the reorganization of health services (1947) was the concept of regionalized health services on a foundation of rural health centers. In each Five-Year Plan, there has been steady progress toward the objective of one rural health center for each community development block of about 70,000 people. More than 5,000 are scheduled to be completed by the end of the present Five-Year Plan period.

Gradually, the idea has been accepted that an essentially new type of doctor is neeeded to work effectively in a rural health center. Medical colleges are going through a dramatic reorientation that is best illustrated by the fact that foreign professors are no longer taken around to see only the show-piece electron microscope; the new status symbol is the teaching health center. Even more important is that many of the best physicians in a diverse range of medical specialties are enthusiastically offering to participate in developing the new patterns of health services demanded by village conditions. Increasingly, one hears clinical specialists say: "Rural health work is too important to be left to public health and preventive specialists. We have to take over."

It is gratifying that several medical colleges are setting up programs in which clinical professors commit themselves to rotating service in villages. These include such prestige institutions as the Ludhiana and Vellore Christian Medical Colleges, the All-India Institute of Medical Sciences, and the Trivandrum Medical College. Perhaps of even more eventual significance is the beginning of a change in attitudes toward research. No longer is prestige attached only to the work that requires the most expensive laboratory equipment. The Indian Council of Medical Research – and scientists generally – are recognizing the greater value of field projects in

[1] Bhore, J. W. (chairman). Report of the Health Survey and Development Committee, India (Delhi, 1946).

which the scientist tries to ascertain the health problems of villages and then to adapt simplified technical tools to discover causation and control measures. The health problems of village India that are beginning to receive attention may be grouped under five headings – technical, cultural, administrative, functional, and educational.

The technical aspects of rural health present a major difficulty in logical planning because we have not really known what the problems were. Medical thinking has been bound too much to the stereotypes of diseases seen in hospitals. The gross inaccuracy of statistics drawn from hospital sources is illustrated by a finding that has now been generally confirmed. In several parts of India, tetanus was not recognized as a major health problem until careful surveys of deaths in the first month of life revealed its frequency. In Punjab villages, tetanus ranks fourth as a cause of death, but the cases never reach the hospitals.[2] Prevention requires only that *dais* and midwives be trained in simple aseptic care of the umbilical cord, and especially that they stop the practice of applying cow-dung ash to the umbilical stump.

As another example, Drs. Scrimshaw, Gordon, and I have worked for the past seven years on a World Health Organization monograph[3] analyzing the interaction of nutrition and infection. It becomes increasingly evident that the first cause of death in the world is probably a synergism between malnutrition and common infections. It produces the widely recognized demographic phenomenon that, in most of the developing world, approximately half of all children die before reaching adulthood. Where nutritional levels are marginal – and especially during the nutritionally traumatic weaning period, when the baby goes from the breast directly to an adult diet – any common infection will precipitate severe malnutrition. Conversely, malnutrition itself lowers resistance, so that the common infections of childhood, which are inconsequential in the well-nourished, become devastating and produce the familiar high rural fatality rates from diarrhea and measles.

Villages are ideal units for epidemiological research. Populations tend to be stable. They are divided into interesting stratifications, representing biological and sociological variables that permit an imaginative research worker to test hypotheses almost as precisely as in laboratory experiments. Village people also tend to be wonderfully cooperative. If one is at all intuitive in understanding their sensitivities, and especially if a modicum of medical help is provided, villagers will happily cooperate with anything reasonable.

The sociocultural context in which rural health services are provided

[2] Gordon, John E., Sohan Singh and John B. Wyon, "Tetanus in Villages of the Punjab: An Epidemiological Study," *J. Indian Med. Assn.*, 1961, Vol. 37, pp. 157–161.

[3] Scrimshaw, Nevin S., Carl E. Taylor, and John E. Gordon. Interactions of Nutrition and Infection, World Health Organization Monograph, to be published.

produces another set of problems. It is scarcely necessary to reiterate that there is a wide gap between health professionals and villagers in their understanding of health and disease. Most Indian doctors do not bother (any more than do many of their colleagues in the United States) to explain to village people what is wrong with them or what they should do. Questions about diet and special precautions are brushed aside, even though they are considered terribly important in the village culture.

On the other hand, when I have observed well-motivated Indian doctors making explanations to their patients, or when I have gone through this exercise myself, the experience has tended to be discouraging. Having grown up in northern Indian villages while my father was doing rural work as a medical missionary, I have taken particular pains to try to learn the village vocabulary in both Hindustani and Punjabi. It is not a matter of using the right words or village expressions. The gap is basically in conceptualization of what disease and health are.

We have completed a research project to find out what Indian villagers believe about the causation of disease, appropriate care, and preventive procedures.[4] These ideas are distortions of ayurvedic medicine. In eight village groups, representing major regional differences in all parts of India, we have had Indian social scientists undertake a depth analysis of health attitudes. From these data we expect to prepare a textbook to help Indian medical students begin to understand what their patients are thinking.

Regional variations are enormous; here are a few examples. The most common cause to which the occurrence of tuberculosis was attributed in villages in Bombay, Madras, and Punjab was infection or contagion, but in Uttar Pradesh it was attributed to impurity of the blood. In Kerala, 99 per cent of the people said tuberculosis was caused by trauma to the chest, and near Nagpur, 73 per cent said it was the result of sexual overindulgence.

Villagers' conceptions of the cause of diarrhea ranged widely. Some 85 per cent of Punjabis said that it was caused by eating too much – and with Punjabis this may occasionally be true. Seventy-two per cent of villagers near Bombay said that diarrhea was caused by eating spoiled food; 93 per cent of those near Trivandrum and 69 per cent of those near Lucknow attributed diarrhea to incompatible foods – that is, foods falling into the wrong humoral categorization, especially in terms of "hot" and "cold" distinctions. The hot and cold foods were independently studied because village people hold firmly to convictions that only cold foods should be taken for particular diseases and in certain seasons, and hot foods under other circumstances. The distinction is based on their conception of how that food affects the body. Such beliefs may control the acceptance or re-

[4] Beliefs about Disease, Treatment and Nutrition in Village India. International Health Monograph Series (Baltimore, The Johns Hopkins Press), to be published.

jection of relief supplies from outside the country during times of famine. We found that many foods considered hot in north India are cold in south India, and vice versa. For instance, wheat is considered deleterious to health in the south because it is hot.

To return to the subject of diarrhea, it is commonly thought to be caused by dislocation of the umbilicus, a belief held by 77 per cent of villagers near Nagpur, 70 per cent of those near Vellore, and 58 per cent of those near Bombay. This is relieved by appropriate abdominal massage. When asked the important question of whether diarrhea could be prevented, a strongly positive answer was given only by the villagers near Bombay. A strongly negative answer was given by villagers in Madras, while most of the rest of the areas were evenly split in their opinions.

Cholera was attributed to the wrath of a goddess by 70 per cent of the people near Vellore and almost half of the villagers near Lucknow and Nagpur. Near Bombay and Trivandrum cholera was thought to be caused by sudden changes in the climate, and in the Punjab 87 per cent of the people said it was caused by drinking water after eating melon. Leprosy was frequently attributed to past sins. Tetanus was said to be caused primarily by supernatural causes.

If doctors are aware of what villagers are thinking, they can use the dramatic effects obtained in treatment to educate the people. Then, perhaps, villagers can be persuaded to do something about prevention and control.

The third problem is administrative. Major administrative changes are needed if a system of medical care is to be provided within the resources available. Political pressures are forcing increasing attention to uneven distribution of health services. Since Independence, Indian villagers have gradually become aware of their political power. High on their priority list of wants is medical care. Although ayurvedic and other traditional practitioners still occupy positions of considerable prestige, it is generally recognized that Western medicine is better for certain conditions.

Politicians have campaigned on overgenerous promises of totally free medical care. It has become increasingly obvious that the total volume of medical need cannot be met through tax sources. Attention is turning not only to efforts to optimize the provision of services through the best possible planning and organization, but also to various ways of getting public participation in health insurance. The private sector of medical care will undoubtedly continue to be active in urban areas. In rural areas, however, the only reasonable alternative is a government program of comprehensive care, combining preventive and curative services in rural health centers.

The only way in which one doctor can hope to meet the medical and health needs of population units of 70,000 or more is by using a much greater number of low-level health auxiliaries. These are not subprofessional doctors, but people well-enough trained to carry out many routine activities that now consume a doctor's time. Most of the diseases seen in health centers are simple conditions that village people bring to the center because they cannot distinguish between the serious and the trivial. Most patients come from within a radius of one or two miles, so that instead of serving 70,000, the health center really serves a population of only about 5,000. The doctor's time should be used for activities only doctors can perform, and other means should be developed to handle routine problems and, especially, repeat visits. This requires the application of simplified operations research, analytical methods, and a high degree of administrative innovation.

There is much that we already know. The health center must be made a decent place for a doctor to work. In our rural health research project, we have been able to rank the 30 or more good reasons for *not* working and living in a village, according to their relative importance for young doctors trying to make a career choice. The most important considerations, in order of priority, are these: provision of adequate drugs, supplies, and equipment; educational facilities for children; transportation; consultation and referral; opportunity for professional advancement with credit for rural service; journals and medical publications; and, only after all of these, a special rural allowance of extra money and better housing.[5] It is encouraging that these young doctors placed professional considerations ahead of personal living amenities.

Another survey,[6] this one of doctors already in rural health centers, showed that they gave greater priority to personal considerations. Conditions will probably never improve sufficiently to attract a sufficient number of doctors spontaneously. Some sort of compulsion will probably be needed, so the present governmental proposal seems reasonable – that is, to have every doctor serve two or three years in a rural area as a normal part of his career advancement.[6]

Development is largely a manifestation of education. Nowhere is this shown more clearly than in the need for educating skilled leadership. Preliminary analysis of early findings of our just-completed five-year research project on the rural orientation of physicians already shakes some basic preconceptions. One simple question of practical importance is whether students with a rural background should be given preference.

[5] Attitudes of Doctors toward Rural Service. International Health Monograph Series, (Baltimore, The Johns Hopkins Press), to be published.

[6] Takulia, Harbans S., Carl E. Taylor, S. Prakash Sangal, and Joseph D. Alter. The Health Center Doctor in India, International Health Monograph Series (Baltimore, The Johns Hopkins Press, 1967), pp. 49–53.

For many years, rural students have been unjustifiably maligned with the familiar comment that, once they have become used to the advantages of city living, they will never go back to village work. A battery of questionnaires and psychological and performance tests has been used on more than a thousand rural interns from all over India.[7] Although rural students do get weaned away from the village as a result of their urban experience, they are never as alienated as urban students. Even more important is the finding that when the former are put into a rural situation, they learn more rapidly and effectively what should be done to meet rural needs. Methods of encouraging rural students include scholarship aid and research institutions in rural areas.

Other findings of our project show that the emphasis on rural medicine and the community approach must permeate the whole medical curriculum. The involvement of clinical faculty is crucial because they are role models for medical students. There are many advantages to the development of decentralized medical education with satellite comprehensive-care units. These rural hospitals provide opportunity for students to learn how to meet common disease problems with realistic organizational and technical resources. The young doctor should not be forced to try to bridge the tremendous technological and intellectual gap between the present university medical center and the facts of professional life in a rural area. A high level of professional and educational support is needed as he makes this transition. When the gap between quality and realistic practicability is too great, the young graduate tends to give up the quality.

Of primary importance in the scientific application of medical knowledge to the needs of the subcontinent is the development of a new quality of ethical and motivational concern. When the medical student becomes a professional he acquires the values and ethical standards set for him by his medical heroes, usually his teachers. How well a faculty member demonstrates, in his own daily living, an ethical dedication to service really determines whether he deserves the title of doctor in its Greek meaning of "teacher."

The need is stated well in a striking passage from Rabindranath Tagore, the father of rural uplift work in India. In a lecture in 1915, he said:

> . . . the minds of the educated now soar in the realm of thought, like clouds in the sky, far away from the earth. The two could be brought together in fruitful union only if they [the clouds] were to melt and descend in the shape of rain. The new monsoon of this new age will have come in vain, if all this imposing preparation roams on in the sky only in wind and vapour. Not that there has been no shower, but the fields have not been ploughed. Nobody yet pays any attention

[7] *See* Footnote 4

to those places which alone, if properly irrigated by ideas, can grow a rich crop. This gray, dry, parched earth, gaping in thirst, is now sending up to the heavens its tearful cry: "Your grand display of ideas, all your stored-up knowledge, it can only be for me. Give it to me! Oh let me have it! Prepare me to receive it all! I shall give it all back a hundredfold." The burning sighs of mother Earth have at long last reached the heavens, the rains will set in soon. It is now high time to get to the cultivation of the soil.[8]

[8] Sen, Sudhir. Rabindranath Tagore on Rural Reconstruction (Calcutta, Visva-Bharati, 1943), pp. 40–41.

Family Planning in India

SHELDON J. SEGAL

THE POPULATION OF INDIA, now more than 500 million, has increased by 120 million in the last fifteen years and is currently growing by about 2.4 per cent a year. It is highly unlikely that India's economy can sustain this burden, even allowing for progress in economic and agricultural development at a pace enhanced beyond that so far achieved and allowing for the most liberal possible foreign aid. Birth rates must fall or death rates will mount tragically, as economic and political stability falter under the pressure of mounting numbers. For India, the birth control dilemma is not whether to adopt a national program officially but how to implement a program as rapidly and effectively as possible.

India's objective is to reduce the birth rate from the current figure of 40 per 1,000 population to approximately 25 per 1,000. Indians produce over 20 million babies a year, as compared to fewer than four million in the United States. In order to reach the goal of 25 births per 1,000 in 1975, there will have to be 10 million fewer births in 1975 than are occurring annually at the present time. This means that 30 million couples must practice effective contraception in that year. At the present time, approximately five million Indian couples use contraceptive methods. The objective, therefore, is a sixfold increase as rapidly as possible. This is not an unattainable goal. It can be done and, indeed, a momentum toward success appears to be gathering.

The government of India first adopted an official family planning program in 1954. Central government budgetary allocations soared rapidly from a negligible sum in the first Five-Year Plan to $10 million in the Second Plan, to an actual expenditure of $54 million and a ceiling of over $100 million in the Third Plan. The Fourth Plan provides $300 million with assurance from the Planning Commission that more funds will be made available if necessary.

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Until 1963, the major strategy was to establish clinics that would provide contraceptive services. Almost all clinics were operated by state governments, local bodies, or voluntary organizations, with financial assistance from the central government. By March, 1963, there were 8,500 such centers scattered throughout India.

At the outset, the Union Health Ministry established a Directorate of Family Planning, which cooperated with parallel subsections in the health services of almost every state. Operationally, the Directorate was responsible for extension education, provision of supplies, personnel training, and support of research on scientific matters pertaining to family planning. Through the years, huge volumes of pamphlets, folders, and posters were produced and distributed to the states. Programs to provide instruction to the illiterate portion of the population were developed. One such project brings village leaders together for orientation in family planning. In another successful program, honorary family planning education representatives were appointed from among civic leaders at the national, state, and local level.

The cumulative impact of the many imaginative extension education efforts resulted in an amazing public awareness of the concept of family planning, particularly in urban areas. A representative study in Mysore State indicated that 38 per cent of urban couples and 11 per cent of rural couples knew about birth control methods. Surveys of attitudes are even more encouraging, in that nearly 72 per cent of India's 100 million couples in the reproductive age group express a desire to limit the family to three children.

This success in awakening public interest is a credit to the sustained educational efforts of the family planning program. In the early years, however, the program's serious shortcoming proved to be in actually providing the service. The great gap between precept and practice of birth control is dramatized by the comparison of the number of interested couples, 72 million, and actual contraceptors, a maximum of five million.

This realization led in 1963 to a plan for complete revision of the family planning program. The new plan would provide full-time family planning workers in state health facilities down to the village level. The objective was to make family planning education, services, and supplies available without the stifling dependency on the clinic. In a realistic evaluation of available contraceptive methods, the plan was designed to provide a free flow of supplies and community education for a family planning program based mainly on use of the condom and/or male sterilization. As later events showed, it was fortunate that a basic administrative structure was created that could, with minor adjustments, be used to introduce new methods of contraception that might become available.

The revised plan was approved by the Central Family Planning Board in October 1963, just fifteen months before the Indian Council of Medical Research was to make an important recommendation destined to have a far-reaching effect on the new program. At Aurangabad on January 20, 1965, the Indian Council of Medical Research recommended the introduction of intra-uterine contraceptive devices (IUD). This decision followed two years of careful study of the method by a distinguished group of Indian investigators. The speed with which they evaluated this new contraceptive method was a great achievement.

Much of the credit belongs to the then Director of Family Planning, Dr. B. L. Raina, who, through the years, stressed building a sound scientific base for family planning. He had developed a strong program of support for research on reproduction. Thus, the organizational structure already existed when Indian science was called upon to evaluate a contraceptive method that held great promise if it proved both effective and safe under Indian conditions.

Aware of the limitations of both conventional contraceptives and the imported and expensive oral contraceptives, the Directorate of Family Planning at once recognized the advantages for India of a method that would not require replenishment of supplies, that did not depend on sophisticated education for use, and that could be manufactured at extremely low cost in India without expenditure of foreign exchange. The Indian Council of Medical Research organized a cooperative study that included nearly 50 clinical units. Within two and one-half years, objective data on more than 5,000 cases had been assembled. This work led to the conclusion that the method could be both safe and effective. This was the most complete evaluation of a contraceptive method ever undertaken in India.

Steps were then begun to manufacture the approved device, the plastic loop, in the public sector. In a matter of months, a government factory in Kanpur was in production and was making the devices at the rate of 14,000 a day. Meanwhile, the initiation of field trials in a number of states was facilitated by a grant of over one million devices manufactured in the United States and given by the Population Council of New York.

For practical purposes, India's new IUD- and sterilization-oriented family planning program began in April 1965. The actual achievement, in terms of providing effective contraception, is encouraging. At the end of 1964 two million Indian couples were using conventional contraceptives or had accepted male sterilization. From April 1965 onward, all the states introduced IUD insertion programs to whatever extent existing facilities and manpower permitted. By December 1966, nearly one million IUD insertions had been achieved and approximately 500,000 sterilization operations performed. By December 1967, the IUD insertion figure had risen to over two million and, with an emphasis placed on sterilizations during most of 1967, more than two million operations had been performed. Thus, in two and a half years India more than doubled the performance of the previous twelve years in terms of actual initiation of contraception.

During this period significant organizational changes were instituted. On the recommendations of a cabinet committee during 1965, the Ministry of Health was redesignated as the Ministry of Health and Family Planning, the Directorate of Family Planning was dissolved, and the upgraded post of Commissioner of Family Planning was created. At that time, however, there was no general reorganization of the administrative structure at either the central or state level. This important step was taken slightly later – in April 1966—in accordance with the recommendations of a special committee charged with the responsibility to suggest administrative and programatic changes, taking into account the impact of the IUD and the recommendations of various evaluation groups, which included a team sent by the United Nations, a mission from the International Bank for Reconstruction and Development, and the Planning Commission.

The crucial recommendation of the special committee (chaired by Mr. S. Mukherjee, Secretary, Ministry of Health) was the establishment of a highly autonomous Department of Family Planning with technical and secretariat wings that are independent of the parallel structure for general health services. This meant that in the central government a large corps of technical and secretariat personnel were assigned full-time responsibilities for the family planning program. A total of 27 officers were delegated the assignments that had previously been the overwhelming burden of the small office of the Director of Family Planning. This change at the central level had great significance in upgrading the status of family planning as a national program, and in providing the center with the mechanism to assist the states in actual implementation.

Concurrently, each state established a network of personnel concerned exclusively with family planning. To encourage this important development, the bulk of the finances required was provided by the central government. In addition, many specific central government grant programs were established to subsidize training of personnel, incentive payments for motivational efforts, utilization of voluntary organizations, incentive payments to private physicians, and so forth, all designed to maximize the states' family planning efforts.

An analysis of the organizational structure within a single state gives some insight into the magnitude of India's program. Within each state health department is a cell concerned exclusively with family planning; this state family planning bureau is headed by a joint director of health services.

The personnel that is provided for a typical state bureau totals about 45. Since the district, an administrative unit of approximately one million population, is the most important operational unit in the family planning program, the program provides for amply staffed district family planning bureaus, each headed by a district family planning officer. To each district bureau are attached a mobile sterilization unit, a mobile education and publicity unit, and mobile units for IUD work. The aim is to provide one IUD mobile team for 500,000 population. A typical district, therefore, serving a population of one million, would have at least 37 people working full time in family planning operating from the district headquarters, contributing to the educational and motivational efforts, and providing clinical services for IUD use and sterilizations. The personnel at the district headquarters would include four physicians, one health educator, one statistician, an administrative officer, and supportive personnel. The fully equipped bureau would have four vehicles assigned for full-time family planning activities.

Complete staffing of district family planning bureaus for India's 336 rural districts will require more than 3,000 trained specialists and a total of 12,000 people at all levels. Adequate staffing of professional personnel in the district bureaus is still seriously deficient in some states. Although virtually every rural district in India now has a district medical officer (family planning), approximately half of the authorized positions for additional medical personnel remain unfilled. However, these are not the only doctors working in family planning with full-time government salary. Urban and district hospital clinics, rural clinics, mobile teams, and clinics operated by voluntary organizations, industrial and health insurance clinics, and so on also provide full-time family planning services with subsidization by the central government.

At each community development block with a primary health center (approximate population of 100,000), funds are provided for a full-time family planning staff, including a doctor. The plan locates full-time workers in residence in rural India, at units below the district headquarters, at the rate of 325 per million of population. This requires the recruitment and training of one quarter of a million workers for rural India.

Training obviously becomes an important requirement. Provision has been made to create a state training center for every ten million population. These centers will offer training for all categories of family planning workers in the field. By 1968, 32 such authorized centers were functioning, and approximately 30,000 personnel had been trained.

To offset the shortage of medical personnel, a number of incentive plans have been adopted to utilize health services physicians for family planning and to enlist private doctors in the program. Government medical officers, who are not specifically full time in family planning, are offered supplementary remuneration for performing sterilization operations or IUD insertions over and above their normal duties. Many states employ part-time private physicians, particularly lady doctors who are housewives, to work in family planning clinics. The involvement of private physicians has become more evident, partly because of adequate financial incentive. For long-range mobilization of medical manpower, the government of India is offering 1,000 fellowships each year to medical students in return for a commitment to work one year in the family planning program for each year of fellowship. By 1968, over 2,000 of these fellowships had been accepted.

Meanwhile, the Department of Family Planning has created a task force of doctors, recruited for special family planning training and assignment away from home, usually at inadequately staffed district headquarters. These doctors are paid a premium wage scale by the central government and assigned to states upon request. They are used chiefly for mobile IUD insertion teams. Each task-force doctor averages 20 to 22 working days per month and an average of 20 IUD insertions per day. A task force of 1,000, as authorized, has the potential of five million IUD insertions per year.

Thus, since 1965, the government of India has embarked on a massive administrative reorganization to close the gap between precept and practice of family planning. The availability of services is now widespread throughout urban and rural India, even though staffing of the program and adequate training of personnel is far from complete. By actual performance, the existing network of services has demonstrated the capacity to initiate nearly one half million contraceptive events (sterilization operations and IUD insertions) in one month. That this level has not been attained on a regular, constant level reflects deficiencies that still exist with respect to motivational efforts and the implementation of available incentive programs. For the program to perform up to its maximum potential, individual states must take the initiative to utilize fully the support offered by the central government.

Supportive activities at the center continue to expand as soon as a need is identified. For example, to assist the network of state training centers, the Department of Family Planning has established six regional offices, each staffed to carry out a training function for family planning field workers. The support of scientific research on the biology of reproduction and fertility control remains of high priority so that, as new methods of contraception become available, they can be tested under appropriate conditions. Despite the tremendous demands on its funds to provide health services, the Ministry of Health, Family Planning and Urban Development (the combined ministry created in October 1967, and elevated to cabinet status) offers liberal grants-in-aid to Indian universities for research in the physiology of reproduction. In the Fourth Five-Year Plan nearly $10 million have been earmarked for this purpose, and additional funds are being sought from foundations and international agencies.

In 1968, a large-scale field trial of oral contraceptives of the estrogen-progestin combination type was launched throughout India. The program, involving 100,000 women, will evaluate the role that these hormonal preparations can play in India's program. Other potential methods, both from abroad and developed from indigenous research, are constantly under surveillance. India's leaders recognize that no single method of fertility limitation may be expected to satisfy the country's heterogeneous population. An effective method may be perfectly acceptable for one segment and of limited usefulness for others, for reasons of culture, religion, environment, nutrition, availability of medical services, or even physiological differences.

Underlying the entire family planning of India is the belief that the provision of this specialized medical service, along with a concerted motivational campaign for its use, can change the traditional pattern of high fertility, a pattern that is the product of centuries of cultural and social development. There is no doubt that the ultimate transition to a small family norm will evolve along with economic development and modernization. Yet, this process can undoubtedly be hastened by the program that has now been launched. The results until now provide a basis for optimism.

Agricultural Science in South Asia

A. H. MOSEMAN

As WE LOOK at agricultural development in South Asia, we might select India as the best example of what has been done and what is under way. Before India achieved Independence in 1947, it had strong research programs in certain fields. Many were in theoretical areas, such as plant genetics and oil seeds. We often fail to recognize that many improvements in the sugarcane industry in the United States are based upon varieties that were developed through the excellent research at the Central Research Institute at Coimbatore.

Beginning with Independence, the new Indian leadership began to take stock of what it must do to improve agricultural production and related education throughout the country. The first University Education Commission was established in 1948 to study broad aspects of education, including that related to agriculture. The report of the Commission was the first to mention the importance of setting up "rural universities." In 1952, when the United States foreign aid program was established, the Technical Cooperation Mission in India also studied the need for research and education in Indian agriculture. An outgrowth of this preliminary study was a plan for a review by teams of Indians and Americans.

In 1955, the first Joint Indo-American Team was appointed. It was composed of five leaders of Indian institutions, including the Indian Council of Agricultural Research, the Indian Agricultural Research Institute in New Delhi, and the State Ministry of Agriculture of West Bengal. I served on this first team, and we spent about three months in India on a widespread survey of research and educational institutions. This followed a similar three-month visit to the United States by the Indian members of the team, who studied the American agricultural and educational systems. Specific recommendations then were made – not massive and broad-sweeping ones, but about 118 precise proposals that we felt government leaders in India could adopt as conditions warranted.

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In 1956, the government of India invited The Rockefeller Foundation to implement some of the recommendations, particularly those concerned with establishing a postgraduate school at the Indian Agricultural Research Institute and initiating research to improve some of the cereal grains, particularly maize, sorghum, and millet. Over the past ten years, The Rockefeller Foundation has furnished guidance for restructuring the organization and program of the Indian Council of Agricultural Research (ICAR), which only recently named a scientist—B. P. Pal, former director of the Indian Agricultural Research Institute—as its director. To follow up the development of agricultural education and research centers since 1956, the United States Technical Cooperation Mission has supported the request made by the government of India that five American land-grant institutions furnish guidance in developing Indian colleges of agriculture and veterinary schools.

In this effort, the original emphasis was to improve the existing institutions in India, but after a few years increased attention was given to the establishment of new "agricultural universities." Involved in this program are the Universities of Illinois, Missouri, Tennessee, Kansas State, and Ohio State. Each is concerned with a specific region in India. For instance, the University of Missouri is working in the northeastern part of the country in the states of Assam, West Bengal, and Bihar; the University of Illinois is working in north central India; Ohio State is in the northwestern part of the country, and so on.

The postgraduate school at the Indian Agricultural Research Institute (IARI) was established in 1958, and by the time of the IARI convocation in 1965, 171 PH.D. degrees and 400 M.SC. degrees had been awarded. The yearly enrollment in the school is about 400, with almost half the students working toward their doctorates and the balance for their master's degrees.

From the beginning, research on maize improvement was designed to channel support from the Indian Council of Agricultural Research into a coordinated, nationwide program that involved institutions under the national government, the state ministries of agriculture, and, as the agricultural universities emerged, the experiment stations of those universities. This formed a pattern that was new and different in the Indian scheme of things. However, it is not too different from the system in the United States, in which the United States Department of Agriculture furnishes an overlay of support to and through the state agricultural experiment stations. The Rockefeller Foundation furnished only a few of the professional staff, and special efforts have been made to encourage maximum participation of competent young Indian scientists who can take over leadership as rapidly as possible. Other crop-improvement research programs assisted by The Rockefeller Foundation relate to sorghums, millets, and wheat.

After the hybrid maize program had been in operation for four years, adapted hybrids suited for Indian conditions from the Himalayas to the south Indian plateau were selected. The hybrids can increase yields from 50 to 150 per cent over that of native varieties. Similar increases are obtained through use of new varieties and hybrids of sorghums and millets that utilize some of the male sterile lines found through research programs in the United States (see Martin Weiss's paper, page 175, this volume).

More recently, research initiated on wheat improvement was built on short-strawed varieties developed in Mexico. They can adjust to high levels of fertilizer and produce yields that are from fourfold to fivefold greater than yields of varieties now growing in India. In the past year, steps have been taken to develop a similar nationally coordinated scheme for rice improvement, with basic germ plasm materials obtained primarily from Taiwan. The Taiwan varieties have the potential to increase yield from 5,000 to 7,000 pounds per acre, as contrasted with normal Indian-variety yields of about 1,000 pounds per acre. It is also possible to increase yields if one puts fertilizers on the Indian varieties, but in view of the magnitude of India's demands for increased food supplies, it seems sensible to utilize the maximum available potential of the new fertilizer-responsive varieties.

Agricultural universities have now begun to emerge. Of the seven that have been established, the one in the Punjab at Ludhiana is perhaps the most advanced. The vice-chancellor of this university is P. N. Thapar, who at one time was the Secretary in the Ministry of Agriculture of the government of India. Another rapidly developing university is in Uttar Pradesh at the Tarai State Farm. In 1957, when The Rockefeller Foundation was selecting locations for the regional maize-improvement research centers, the Tarai State Farm was chosen because the state government was thinking of establishing an agricultural university in that location. The maize-improvement scheme has furnished the nucleus for the university research station. Agricultural universities are also coming into being in Orissa, Mysore, Andhra Pradesh, Madhya Pradesh, and Rajasthan. All are in different stages of growth and in different stages of growing pains, because these new ventures require a great deal of both local and outside guidance and leadership.

As we look at the future of agricultural science and technology in India, we see emerging a new and effective pattern for utilizing central government and state government resources. The cooperating personnel from The Rockefeller Foundation have backed away from coordinating leadership of the maize program and have transferred it to Indian government personnel. The Foundation staff is using the base that was established at the Tarai Agricultural University to expand corn improvement research into other countries in Southeast Asia and the Far East, including Thailand, Indonesia, Malaysia, Viet Nam, and the Philippines.

International leadership also is emerging in India, which may become the principal research center for improvement of sorghums and millets for food use. The largest collection of sorghums and millets in the world has been developed at the Indian Agricultural Research Institute. It is now being evaluated for productivity in India and for cooperative programs in Africa and other areas of the world.

It is essential that we continue to improve worldwide collaboration in agricultural science. We are taking steps at the moment, under AID support, to enable the International Rice Research Institute to participate more actively in the National Coordinated Rice Improvement Scheme in India.

The agricultural universities in India have been established primarily as educational institutions and do not yet have the broad competence that is found in the American land-grant colleges. A greater research component must be incorporated in Indian universities. We are now reviewing this, in cooperation with government of India personnel, and hope to expand university research to help increase production of the major food grains. This would mean strengthening the universities' participation in nationally coordinated crop-improvement research programs.

In looking ahead to technical cooperation in agriculture, national systems of research and development should be planned. Previous public and private technical assistance programs have tended to select an American institution for a given job in a given location in a host country. Cooperative effort may thus become isolated and provincially oriented. In the United States, the importance of a land-grant university has been both its integrated attention to education, research, and extension in a particular state or local area, and the combined impact of 58 such institutions. All were independently established, but were closely interrelated through their own efforts and through the coordinating research programs supported by the United States Department of Agriculture. This integration, or network, does not yet exist in India and should be developed in the years ahead. Such national or regional cooperation will be important in the future.

In planning how to meet future food needs, India is depending heavily on increased productivity of Mexican wheat and Taiwan rice varieties. They are shipped from great distances, and there are many unknowns as to how they will behave in strange environments. We never know how destructive local pests and diseases may be to introductions from distant places.

Again, we can take a lesson from our experience in the United States with major farm-crop diseases. In 1950, for example, a new strain of wheat rust was noticed in the United States. In 1953, it caused a 65 per cent loss in the durum wheat crop. The following year 75 per cent of it was lost. These are the kinds of biological factors we confront as we move vigorously to bring new crops into new environments, where they may confront unknown hazards. It is important that countries establish research systems that can detect production difficulties and keep ahead of them.

More attention must also be given to land and water resources and use in India. In this problem area, outstanding progress is possible in the next few years. Again, it must be addressed in concert with attacks on other vast problems and not on a piecemeal, intermittent basis.

In assessing India's food requirements and production in recent years, the importance of an improved program of agricultural science and technology is obvious. In 1960, the country produced about 78 million metric tons of food grains. That rose to between 80 and 82 million tons in 1963. In 1964 it was 88 million; in 1965 and 1966, because of the severe drought, it dropped to about 76 million. Production increased to more than 95 million tons in 1967 as a result of heavy emphasis on the high-yielding new crop varieties with heavier fertilizer use. In order to maintain a rate of increase in food production to meet population growth, India must strengthen institutionalized research and education in the years ahead to provide innovations for growth in agricultural production at a rate of 5 to 6 per cent each year.

A staff member in the Indian Agricultural Research Institute pointed out recently that the modernization and change in traditional agriculture is a problem of the literate, not the illiterate. His implication was that most farmers are willing to adopt new materials and methods from applied science and technology, but the real difficulty is to convince the administrative and political leadership of government and the budget-makers that it is wise to invest in long-range scientific and technological efforts rather than to perpetuate a series of short-range crash programs that will neither alleviate current food shortages or fulfill future needs.

Let us turn briefly to Pakistan. One of the best agricultural research institutes in South Asia at the time of Indian Independence was in the Punjab at Lyallpur, in the major breadbasket of what was formerly India. In recent reviews of agricultural progress throughout the world, Pakistan rates high. The growth rate has been about 7 per cent annually over the last four or five years. However, if we look at how this was achieved, we find that much of the added output came from bringing in new land and water resources and by utilizing available technology, including improved irrigation practices, better crop varieties, and increased amounts of fertilizers.

AID staff members and government of Pakistan agriculturists in Karachi recently said very frankly that they were running out of resources or new inputs, and increasing production in the years ahead would depend upon the availability of new knowledge. As they put it, "We're running out of 'intuitions' as to what to do; heretofore we could go out and, say, throw on a bag of fertilizer; now the question is, do we throw on another bag of fertilizer or do we do something else?" Pakistan must give added attention to science and technology if it is going to keep up the pace of agricultural growth it has demonstrated so ably until now. Pakistan, like India, is looking to varieties of Mexican wheat and Taiwan rice to improve agricultural production.

Adequate attention should be given to developing institutions within Pakistan that can carry out sustained research and adaptive studies. No nation should be dependent, for any extended period of time, on outside sources of agricultural science and technology. The International Rice Research Institute in the Philippines will make a real contribution over the next five or ten years, and the Mexican wheat program will also be most helpful over the short run. It is extremely important that Pakistan, as well as India, move vigorously to establish the kind of institutional base – a national system of agricultural research and education – that will enable it to be fully self-sufficient in expanding agricultural growth in the years ahead.

Research for Agricultural Development in South Asia

MARTIN G. WEISS

OVER THE PAST DECADE, increased food production in the countries of South Asia has been largely attributable to cultivation of additional lands. This chapter emphasizes the possibility of increasing food production through research, without further increasing the land area used for agriculture.

Science has served as a major force in increasing agricultural production in the United States. Let me cite a few examples. The scientific development of cytoplasmic male sterility and the fertility restorer system in the sorghum plant has permitted the use of heterosis in commercial production of sorghum. In the United States, this accomplishment has led to an approximate 40 per cent increase in production.

The incorporation of the semidwarf character into commercially suitable varieties of wheat has permitted heavy fertilizer practices without prohibitive lodging (loss resulting from grain crops falling over before they can be harvested). In the Pacific Northwest, record yields of conventional varieties seldom exceeded 100 bushels per acre, even when grown under irrigated conditions. Record yields of 134 and 209 bushels per acre, respectively, now have been made on rainfed and irrigated land with semidwarf varieties.

Science also has contributed to major improvements in food quality. We have discovered, for example, that certain flourlike genes in corn affect major shifts in the amounts of essential amino acids in the plant. This means that the nutritional value of corn for human beings can be greatly improved. The genetic identification and isolation of glandless genetic types in cotton provide a potential for developing cotton varieties whose

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seeds do not contain the toxic compound gossypol. Oilseed meal from such varieties could be used directly in the human diet.

Such advances could help increase both the quantity and the quality of agricultural production in South Asia. In a recent discussion, the vice-chancellor of the new agricultural university at Bangalore described a university project being conducted in cooperation with the Ministry of Agriculture. A large area of land had been taken over for the production of hybrid maize (see Moseman's paper in this volume). All known improved management practices were put into effect, and the result was phenomenal yields, even during monsoon rains. The vice-chancellor remarked offhandedly that if all scientific advancements to date were put into practice, India today could produce enough food for its entire population.

The current food situation in India is serious. The average diet has been described as some 300 calories per day below that of a desirable maintenance level. Partly because of transportation difficulties, severe protein deficiencies occur, especially in the heavy rice-growing areas. At least 85 per cent of the proteins eaten are vegetable; customs and economic conditions both contribute to limiting the quantities of animal protein in Indian diets.

Research on high protein-producing crops must be given priority. The regional pulse project for the Near East, South Asia, and the Far East, which I describe briefly in the paragraphs following, will illustrate one type of overseas project that the United States Department of Agriculture has recently undertaken with funds provided by the Agency for International Development (AID).

Pulses include the large-seeded edible legumes. Most are bean-like or pea-like. In South Asia, the chickpea (known as Bengal gram) predominates. This pulse is a major crop in both India and Pakistan. Dry beans, mostly mung and urd beans (green gram and black gram), and pigeonpeas (red gram) are the other major pulse crops in the region. Broadbeans, dry beans, cowpeas, and lentils are grown to a lesser degree in South Asia but are predominant in the Middle East.

The objectives of the pulse project include development of improved varieties of pulse crops and improved cultural and management practices, as well as better coordination of pulse research efforts in the countries of the region. In addition, the project seeks to train national junior scientists and establish a corps of specialists in pulse research to whom the program will eventually be turned over.

Regional projects have headquarters at two research centers – one at Karaj in Iran and a second at New Delhi. The Middle East center is staffed with senior American scientists specializing in plant genetics and breeding, plant pathology, entomology, and soil-water-plant relationships. The New Delhi center has a similar group of United States scientists, and a food technologist has also been added. Counterpart national scientists are working in collaboration with the Americans, and the centers include a good number of national trainees and adequate supporting staffs.

At the present time, pulse crop productivity is low. Diseases and insects are prevalent, and management practices are poor. The crops have, in short, received little scientific attention. It may be pertinent to ask why only token research resources have been allocated in the past to crops such as the pulses, which constitute a valuable increment to the diet of low-income families. It is understandable that during colonial periods major research was devoted to export crops and that, even with Independence, the great need for foreign exchange dictated that emphasis be so placed. (Most developing countries have engaged their best scientists to work on cotton, tea, and rice crops.) When we surveyed countries from the Near East to the Far East to find the most desirable locations for the pulse research centers, we were amazed to find that not a single scientist was devoting his full time to these plants.

Thousands of varieties collected from all parts of the world are presently being tested in Iran for productivity, adaptation, and resistance to disease and insect pests. Nutritional quality soon will become an additional criterion. Each country will be encouraged to collaborate by conducting regional tests for promising varieties and production practices. Such projects represent a change in the types of agricultural programs financed by AID. Previously, United States personnel have worked largely in an advisory or consultative role, but in the new type of research project they have operational responsibilities.

Another program was initiated in 1958 by the Agricultural Research Service (ARS) of the United States Department of Agriculture. It is conducted under the authority of the Agricultural Trade, Development, and Assistance Act of 1954, commonly known as Public Law 480. Research is carried on through grants made to foreign institutions, financed by foreign currencies available to the United States Government through the sale of agricultural commodities abroad.

Several types of studies are being carried on. Utilization and marketing of agricultural products were the first. Soon thereafter, research began on agricultural and forest production and on agricultural economics. Like most such grants, these are available only to those institutions that have competent scientists and adequate research facilities. Another criterion is that the research must be of interest both to the United States and to the country concerned. The criterion requiring mutual interest necessarily favors basic research rather than applied, which may be pertinent only for the local country. In agricultural production, nevertheless, a number of kinds of applied research meet the stated objectives.

For example, support is given for research on crop and livestock diseases or on insects not currently in the United States. With modern transportation, the invasion of diseases or insects is a constant threat. It is of interest to the United States to study the characteristics and life histories of such pests and the genetic resistances that could be used to minimize losses.

Biological control of insect, weed, and disease pests now found in the United States is another example. When a new pest is introduced into this country, it frequently has no natural enemies. The cereal leaf beetle is currently highly destructive here, but it is not considered a menace in countries where it has been prevalent for a long time.

Collecting, testing, and preserving plant materials is still another category supported under the program. Research may center on additional germ plasm of domestic plants, wild relatives of domestic plants, and plants with entirely new uses. The latter are studied in screening programs for oils, gums, and waxes that have specific industrial uses. Study and classification of domestic germ plasm sources is an excellent illustration of this type of research. There is a grant to collect, maintain, and classify in India banks of sorghum and millet germ plasm from all parts of the world. These projects cooperate closely with the excellent sorghum and millet research program which is being sponsored by The Rockefeller Foundation.

As of March 31, 1966, there were 174 active projects in India under the ARS grant program. They had a dollar equivalent of approximately 10.6 million. In Pakistan, 14 projects were active, and the dollar equivalent was slightly more than one million.

Finally, let us turn to the role of industrial research in agriculture. In the United States, industry makes vast contributions to agricultural development, particularly in such areas as pesticides, fertilizers, agricultural machinery, and improved varieties of certain crops, such as corn and sorghum hybrids and vegetable crops. In India and Pakistan, industry is not yet in a position to make major scientific contributions to agriculture. Therefore, it is imperative that publicly supported research carry most of the responsibility until industrial research programs can be developed.

Adoption of New Agricultural Practices in Asia

A. M. WEISBLAT

INCREASING AGRICULTURAL PRODUCTION presents many problems in changing levels of technology. The types of inputs, innovations, and new farm practices that will bring about a sustained level of growth are all pertinent factors in achieving the main objective. This means new plant varieties, new ideas about fertilizer, and so forth. But there is another critical factor – getting farmers to accept them.

I will review a few relevant propositions, pointing out possibilities by which new techniques could be adopted by subsistence farmers in Asia – those farmers who raise food basically for their own use and who ultimately move into commercial agriculture.

One major problem is communication. How do we get the villager in Asia to understand our sense of urgency? How do we get him to mobilize his resources as we know he must? To answer this question, we must first define the subsistence farmer and what we know about him. Is he or is he not the "economic man" about whom the economist speaks? How different is he from the Iowa farmer?

We can begin with a definition of agriculture. Agriculture is a deliberate manipulation of biological growth by man to produce more of the goods he wants, either for himself or for sale. Two critical categories affect this manipulation: physical climate, soil, seeds, and so on; and society, cultural values, and the like. We are all fairly clear about the effects of the first category, and are making real progress in manipulating natural factors to increase production. Man-made factors are more complex and not as well understood. As a matter of fact, most of the literature tends to note the negative effects of cultural taboos and traditions and to emphasize social structures as barriers toward increased production.

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We need much more information about the ways in which farmers regard the problems they face. Lacking this, we cannot communicate new ideas or get farmers to appreciate the difficulties of agricultural planning for an entire country. Clifton Wharton, a colleague on the Agricultural Development Council staff, has formulated a proposition that may point the way. The essence of his proposition is that vital decisions in agricultural planning should be made as close as possible to the local level, where conditions and needs are best known. Integration of these decisions can then take place at higher levels of government. Wharton then says:

Past technical assistance efforts have not fully capitalized upon the peasant farmer and the unique characteristics of subsistence and traditional agriculture. On the whole, our agricultural technical assistance program has been problem- and project-oriented to what the problem is and what project will solve it. Execution is usually carried out from the top down. We tell the peasant farmer how to farm better. We identify their problems. Actually, the reverse should be the procedure. We should help the farmer discover for himself what he needs in order to farm better, then develop projects which will serve those needs and problems as he has identified them.[1]

Planning from the bottom up does not always preclude work from the top down. Many things can be done only from the top down – for instance, basic scientific research in agriculture. The peasants and villagers best know their problems and needs. Why do we not build upon this knowledge, but do it in such a way that there is two-way communication, village-to-capital and capital-to-village, based upon the comparative advantages of each? The communication must involve a meshing of needs with services. Most developmental projects are based upon the erroneous, but implicit, assumption that the central government has a greater advantage in all these respects. This may sound extreme. Perhaps it is, but the amount that we can learn by knowing more about what goes on at the village level should be emphasized.

A good bit of work has already been done in this area – in the whole field of community development, for example. Until now, however, the weakness in the approach has been that felt needs were usually predetermined by the community development officer. Some of the goals made good sense, such as road building, teaching, schools, and public health. But to predetermine what the villager needs and then get him to understand and appreciate those needs is like holding a revival meeting! We must know what the villager himself thinks are his requirements. This is particularly true in the area of agricultural production. (It should be added,

[1] Wharton, C. R., Jr. "Strategies for Rural Development" (Paper given at meeting of South East Asian Development Advisory Group), New York, April 1, 1966, p. 17.

in all fairness, that the community development program was not designed to increase agricultural production.)

The peasant farmer should and can be successfully involved in a greater role in agricultural development. He is concerned with his immediate problems, and has knowledge of the localized adaptations required for technological change. The more closely he works with programs devoted to his own pressing needs, the greater the effectiveness of total implementation.

A number of studies illustrate the farmer's realistic attitude. For example, in a study in the Philippines, 75 per cent of the farmers interviewed said that they wanted their children to have more education than they had had. They did not want them to become farmers. However, when asked if they expected that their children would, in fact, be farmers, approximately three-fourths answered affirmatively.

It would seem obvious that farmers know about tractors and other farm machinery, but how much modern machinery is designed for subsistence farmers? The question of whether, in fact, machines can be designed for their use at all should be explored. The prevailing idea seems to be that subsistence farmers have so much available labor that mechanization is out of the question. However, I have yet to meet a farmer in India or in Southeast Asia who would not willingly accept some form of mechanization, assuming a reasonable price, so that he might act like a human being instead of a bullock.

We must also recognize that peasants do react to economic stimuli. Rubber was not indigenous to Southeast Asia, but it is now grown by a fairly large number of small landowners, even though they must wait five or six years before they can get a return on their capital. Corn production in Thailand is another example of farmers adopting a profitable crop. Fertilizer demands in India and Pakistan tell us that there, too, farmers are reacting to economic stimuli.

Economic stimulus for an innovation must, of course, include a substantial return on capital investment. Farmers on a subsistence level are faced with a much higher risk factor than are our Western commercial farmers. I seriously doubt whether any of us, given only a one-hectare farm, would be willing to adopt a new practice or take a risk on a new crop for a possible 10 to 15 per cent production increase. To offer real appeal, the returns should be 50 per cent higher.

We must further recognize that not all farmers are identical, and that it may make more sense to concentrate on a few selected farmers than on a few selected areas. We know from experience that in Asia, as in the United States, some farmers are more receptive to new ideas than others. Not all have the physical, financial, and intellectual resources to experiment with new techniques and to profit by them. One reason for the failure of much agricultural extension in Asia in the past is that limited resources in technical personnel have been spread indiscriminately over the good, bad, and indifferent, rather than concentrated on receptive farmers.

My final point is the potentially important, exciting, and provocative proposition that one of the real training needs in Asia is to give both farmers and extension workers some concept of science. That man can change his physical environment and control nature must be understood. Extension workers must be aware that when they take a new practice or a new crop variety to a farmer, what they bring him has not been handed down from God and the central government, but has been produced on experimental farms. For this reason, the results are based on probability theory and show high return possibilities. Unless this is first understood and accepted by an extension worker, he, in turn, will find it difficult to get a farmer to accept it.

We must find an answer to the general question of how to make farmers understand the concept of science. It would be useful to find receptive farmers and take them to experiment stations. Let them see what an experiment looks like, what experimental plots are. Perhaps microscopes should even be brought into local villages to demonstrate that "science" is not a great mystery. It is essentially a process—a process through which man can begin to control some of the factors around him and on which his life may depend.

Marine Fisheries Resources of South Asia

A. T. PRUTER

PROTEIN, particularly animal protein, is the greatest nutritional deficiency in the diets of South Asian peoples. Experts generally agree that an adequate intake of animal protein is about 30 grams per capita per day; 15 to 30 grams is borderline; less than 15 grams is dangerously low. Per capita daily consumption of animal protein in Pakistan is only 8 grams and in India it is even less – 6 grams.[1]

In India and Pakistan, most of the arable land is devoted to raising plant crops, a pattern that makes it difficult to produce adequate supplies of animal protein on land. Thus, the peoples of South Asia should look to the Indian Ocean for more of their animal protein.

The Indian Ocean is one of the world's three largest. It accounts for over one fifth of the surface area and a similar proportion of the volume of all the world's oceans. Despite its huge size, only about four per cent of the world's harvest of marine fishes is taken from it. To make matters worse, the proportion of the total fish catch from the Indian Ocean has declined over the past 30 years. Between 1952 and 1963, the world harvest increased by 90 per cent, while that from Pakistan and India increased by only 41 per cent.

Why has the fish harvest from the Indian Ocean not kept pace? Of course, there is no simple answer to that question, but there appear to be two main reasons. First, the indigenous marine fisheries of South Asia have not kept up with the technological developments in industrialized

[1] Olcott, H. S. and M. B. Schaefer. "Food from the Sea," *Food Technology*, 1965, Vol. 19, pp. 92–95.

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fishing nations. Second, the Indian Ocean is the least studied and the least understood of the world's oceans.

Before we speculate on its potential resources, let us look quickly at the existing fishing situation. Most present fisheries are inshore, conducted from small boats that often are not even motorized. Large-scale, high-seas fisheries comparable to the distant-water trawl fisheries of European nations or to the world-ranging fisheries of Japan and the Soviet Union simply do not exist in India and Pakistan.

In West Pakistan, threadfins, mackerels, bonito, croakers, and sharks are harvested from inshore waters by gill nets and trawls. Trawling for prawns on inshore grounds also is becoming increasingly important.

India's west-coast fisheries, which account for about three-fourths of the marine catch, are mostly confined to within 10 or 15 miles of shore. One of India's most important fish is Indian mackerel, which occurs south of Bombay to Quilon in Kerala State. They are caught with beach seines, boat seines, and gill nets. Oil sardines contribute the largest catches, but their availability to the inshore fishermen fluctuates enormously from year to year. Fishing for prawns is becoming increasingly important to India, but much of the catch is exported.

Many fishing grounds are available on the broad continental shelf around East Pakistan; however, the monsoons permit only a relatively short season for small craft. The potential of the Bay of Bengal is virtually untapped, partly because of a preoccupation with fresh-water fisheries.

Although fisheries in South Asian countries are primitive compared to those in industrialized fishing nations, some startling progress has been made. An example is the joint Indo-Norwegian fishing project in Kerala, which has led to the use of motorized boats and such modern gear as trawl nets, and to the construction of freezing and distribution facilities ashore. Another example is Pakistan's new harbor and market in Karachi, constructed with United States' aid. These important shoreside facilities, together with the introduction of motorized boats and nylon fishing nets, have increased catches and earnings three to four times over their former levels. The Food and Agriculture Organization of the United Nations has played a large role in making these advances possible.

Despite this encouraging progress toward better utilization of the fish resources, present harvests are still taken mainly by small vessels from inshore waters close to a few large coastal cities. If adequate vessels and fishing gear were available for more distant-water fishing, together with improved fish processing, preservation, and distribution facilities ashore, how much could the Indian Ocean contribute to alleviating South Asia's food problems? This is a most important question, and our ability to provide an intelligent answer hinges upon our knowledge of the expansion potential.

In the face of the great need for information on fish resources, it is extremely unfortunate that the Indian Ocean is so poorly understood. Recognition of this led to the organization of the International Indian Ocean Expedition, which began in 1961, reached a peak of activity in 1963, and has since tapered off. It applied the kind of international cooperation and effort that produced such fruitful results during the International Geophysical Year. Some 25 countries and more than 40 research vessels participated in the expedition, which added greatly to our knowledge of the oceanography and living resources of the Indian Ocean. Benefits will continue to accrue for many years as collected information is analyzed. Here are a few results of which I, as a participant in the expedition, am aware.

One cruise of the United States National Science Foundation vessel *Anton Bruun* was made in the western Arabian Sea to investigate a region where previous casual observations from merchant ships had suggested an abundance of animal life. The *Anton Bruun* found extremely fertile waters in an area of diverging ocean currents some 200 to 300 kilometers off the Arabian coast. Plant production rates in these waters were of an order of magnitude greater than that of the world's oceans as a whole. At two stations off the Gulf of Oman, rates of production were higher than ever before reported for the open sea.

On a follow-up cruise to the same general area, large trawl catches of bottomfish were made off a part of the southeastern coast of Arabia, where there were then no commercial fisheries. The catches exceeded any I have seen taken with similar fishing gear in the productive northeastern Pacific Ocean.

That the waters off southern Arabia, in the Gulf of Aden, and off the east coast of Africa are productive was indicated by the expedition and proved by fisheries that have since been established. Soviet vessels have seined tuna and mackerel along the north Somaliland coast and in the Gulf of Aden. Large Soviet stern trawlers achieved good results with threadfins and other desirable species of fishes along the southwestern Arabian coast.[2] Japanese vessels fish for tuna around Madagascar and between Madagascar and the African mainland.

On the gloomy side, when the *Anton Bruun* took a bottomfish trawling survey in the eastern Bay of Bengal, it made disappointingly small catches. This cannot be accepted, however, as a true measure of the region's possible

[2] Hinds, V. T. "International Interest in Gulf of Aden Fisheries," *Fishing News International*, 1964, Vol. 3, pp. 20–22.

yield. The survey was limited in extent and may have taken place at a time of the year when bottomfish were relatively unavailable. Also, visual sightings and echo soundings made during the survey indicated large schools of pelagic fishes, at or near the ocean's surface, which were unavailable to the bottom trawls used on the survey.

In attempting to assess the fishing potential of waters adjacent to South Asia, we must keep in mind that we are discussing tropical seas. Some investigators believe that fish production from warm waters will never rival that from temperate and cold areas.[3] One reason given is that conditions in tropical seas limit biological production because of a sharp and persistent thermocline that impedes the return of nutrients from bottom waters to the surface layers, where they promote growth of plankton, the basic food organisms of the sea. Only in regions where the thermocline is broken down or deformed by upwelling bottom waters does high biological production occur. The International Indian Ocean Expedition, however, showed that upwelling does, indeed, occur off South Asia, and the very nature of the monsoons, which reverse their direction during the year, creates substantial upwelling in many areas. We also need only look at Peru, a country that borders on the tropical Pacific, to see how rapidly a fishing situation can change. In the eight short years between 1954 and 1962, Peru's fish catch rose from less than one-quarter million to seven million metric tons. Almost overnight Peru became the leading fish-catching nation of the world, replacing Japan, which had occupied that position since fishing records were first kept.

We do not know that comparably productive waters occur in the Indian Ocean. The truth of the matter is that nobody knows the potential of its fish resources – or those of any other ocean, for that matter. One of the great tasks confronting mankind is to explore and investigate these resources to determine their nature and extent. Nowhere is the need greater than in South Asia, where supplies of animal protein are so critically short, where human populations are so dense, and where so little is known about the possible food available in adjacent seas.

Of course, it is one thing to be able to catch large quantities of fish; it is something else again to entice people to use them. Eating is largely a matter of habit and, by habit, the people of some countries around the Indian Ocean are not extensive fish eaters. Where eaten extensively, only a relatively few traditional species are desired. Another obstacle to increasing the amount of fish in South Asian diets is the lack of adequate processing, preservation, and distribution facilities ashore.

Fortunately, a recent development gives high promise of eliminating

[3] Longhurst, A. R. and V. Bainbridge. "Tropical Fisheries Resources," *Fishing News International*, 1963, Vol. 2, pp. 409–416.

in a single bold stroke both dietary prejudices and the lack of preservation and distribution facilities. This is fish protein concentrate or, as it is now often called, FPC, or fish flour. In the United States and elsewhere, processes have been developed to concentrate the protein by methods that remove most of the water and fat, leaving a dry, tasteless powder that can be added to traditional foods as a protein supplement. It seems certain that in time a whole family of new fish products in liquid, powdered, and granular form will be developed that could be most useful in supplementing the diets of South Asian people.

Thus, the arrival of FPC on the world scene gives even greater impetus to the need for scientific knowledge of the subcontinent's fishery resources. Vastly increased exploratory fishing and oceanographic surveys of the Indian Ocean could be one of the wisest and most profitable investments in years to come.

Irrigation Planning and Research in India and West Pakistan

STEPHEN A. MARGLIN

THE VILLAGE OF Dhabi Kalan lies 150 miles northwest of Delhi, in Hissar District of Punjab State. Situated on the edge of the Rajasthan Desert, Dhabi Kalan receives less than fifteen inches of rainfall per year, virtually all between July and September. For this reason land was, less than a hundred years ago, free for the taking.

The Western Jamuna Canal was among the first irrigation undertakings of the British in the Punjab, constructed well before the turn of the century. It brought water over a distance of more than 100 miles into Hissar District, but not to Dhabi Kalan. The distributary came within ten miles, but its meager supplies were allocated to the alluvial soils of a neighboring tract. Dhabi Kalan, along with its sister villages in the desert, subsisted on millets and chickpeas (gram), the most that could be extracted from the parched soil.

Nevertheless, by the time India had gained Independence the increase of population had led to the settlement of even the most marginal areas of Hissar District. Free land had become a thing of the past, and although population density might have been low by Indian standards, the level of living was even lower. At the commencement of the First Five-Year Plan (1951), the rural population of Hissar District was just under 900,000. The gross cultivated area totalled about 2,700,000 acres – in other words, approximately three acres per member of the rural population, three times the national average. But the value of agricultural production, at the average harvest prices of 1960–61 to 1962–63, was less than Rs 150 (about \$32 at the then-prevailing international exchange rate) per member of the rural population.

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By the end of the Second Five-Year Plan (1961), the rural population of Hissar had increased by 47 per cent to 1,300,000, a rate of more than 4 per cent per year. The gross cultivated area increased at a somewhat lower rate, to 3,700,000 acres. These figures suggest no improvement in per capita income. But in fact, at constant prices (prices adjusted for inflation), agricultural production increased by more than 200 per cent, and per capita production by 100 per cent to almost Rs 300 per member of the rural population. The average annual growth rate of agricultural production was 11 per cent and the per capita 7 per cent.[1]

The Bhakra-Nangal Scheme, a half-billion dollar investment to harness the Sutlej River for irrigation and power, made the difference. During the period of the first two Five-Year Plans (1951–56 and 1956–61), close to a million acres in Hissar District alone (and an equal amount in other parts of Punjab) that had never before received irrigation were under the Bhakra scheme. Water was brought to Dhabi Kalan from more than 200 miles away; villages which at times had lacked even drinking water began to produce wheat and cotton, oilseed and sugar cane.

The recent experience of Hissar District is indicative of the impact of irrigation when other conditions are favorable. Yet crop yields remain low, not in comparison with all-India averages, to be sure, but in comparison with potentials – measured either by experiments on cultivators' own lands or by average yields in climatically comparable areas in the United States. Irrigated wheat yields average less than 20 bushels per acre – less than in Kansas, where wheat is dry-farmed. Cotton yields average less than half a bale per acre; California gets more than two bales. Recent experiments in Dhabi Kalan produced more than 40 bushels of wheat per acre and more than a bale of cotton. No secret ingredients; just moderate doses of fertilizers and pesticides. More to the point, these experiments returned Rs 3 to Rs 4 for each rupee the cultivators invested in materials – a handsome return by any standard.

Why are such obviously profitable practices not generally adopted? A primary reason is uncertainty about water deliveries. The only way a cultivator knows if there will be water when it is his turn to irrigate is to look in the canal. Suggest to him that he stands to profit enormously from using fertilizers and pesticides, and he will respond: "Yes, in principle those are

[1] These estimates are based on data from *Statistical Abstracts of Punjab*. Growth rates of agricultural production in constant rupees were estimated from a least-squares fit of the log linear trend over the period 1950–51 to 1962–63. (In fact, rates of growth turn out to be uninfluenced by choice of prices, because relative prices of various crops hardly changed between the beginning and the end of the twelve years in question. The average price level increased about 10 per cent between the beginning and end of this period.)

good things. But if I use them, I'm only sure of adding to my costs. If the water fails to come on time, fertilizer may do harm rather than good."

This seems impossible to believe. The whole point of the 700-foot Bhakra dam was to free irrigation from the extreme seasonal variations in stream flow that characterize the great Himalayan rivers, to store spring snow melt and summer monsoon waters for delivery during the low-flow winter season. Indeed, it *is* technically possible to determine an operating schedule in September to cover the whole *rabi* season, which runs from October planting to April harvest. (The other season in the Indian agricultural year is the *kharif* season.) And the schedule *is* determined, at least for the reservoir.

The canal officials, furthermore, are under instructions to communicate canal operating schedules to cultivators. Still, despite four separate networks of communication – canal revenue officers, canal maintenance officers, development officials, and local institutions of self-government (the last dying on the vine in many places for lack of anything useful to do) – word does not reach the cultivator.

The need for communication about canal operations should be emphasized for several reasons. First, it is one of the most important obstacles to the development of Punjab agriculture. There may not be any miracles if farmers receive irrigation schedules. The farmer just quoted was in part simply rationalizing his failure to innovate rather than explaining it. A potential innovation requires many ingredients for rapid diffusion, and reduction of uncertainty about water deliveries is only one of them. But if not a sufficient condition for innovation, reduction of uncertainty about canal operations is a necessary one.

It is likely, moreover, that Punjab is not the only state in which cultivators' uncertainty about water deliveries could be reduced. No state has had more experience with large-scale canal irrigation than has Punjab, and it is doubtful that many other states manage their storage projects any better.

Finally, it is crucial for our understanding of the process of economic development to fathom the sociology of a bureaucracy that fails to respond to such an obvious need. This is a need, furthermore, which is recognized in principle – witness the instructions enjoining preparation and communication of season-long schedules. Two hypotheses can be suggested to explain the apparently irrational behavior of the irrigation bureaucracy.

First, senior officials of the Punjab Irrigation Department grew up in a totally different technological regime. In pre-Partition Punjab, the enormous network of canals was entirely "run of the river"; that is, barrages simply created enough head to deliver water the requisite distance by gravity flow and provided no storage whatsoever. Hence "scheduling" necessarily had to be limited to a rotational program (canal one shall receive first preference in week one, canal two in week two, and so on); long-term scheduling was a technical impossibility. With the erection of Bhakra-Nangal, the technological environment has been totally changed, but the bureaucracy has yet to respond to that change.

The second hypothesis is less charitable – a desire for secrecy to escape accountability. The canal officer may tremble at the prospect of irate cultivators confronting him with an official schedule in case he has failed to adhere to it. (As it stands, the cultivators always feel they are being short-changed, but they can hardly prove it.) This hypothesis may be less charitable, but it applies no less to the myriad agencies of the United States Government than to the Punjab Irrigation Department – witness the inordinate numbers of documents classified in the United States for no better reason.

Any schedule that reaches the cultivator would be better than none. However, to provide an *optimal* schedule for large-scale storage systems like Bhakra – whose distributaries serve literally millions of acres with a wide variety of soils, rates of natural precipitation, and cropping patterns – is a task of enormous complexity. It is further complicated by power demands, which at times during the year compete with irrigation for water. Even if the crop responses to varying amounts of water and times of application were known, optimal scheduling problems would be enormous. In principle, however, this can be solved, and preliminary research on American and Egyptian water systems with the aid of high-speed, large-scale computers suggest that this is an area in which the pay-off from application of advanced technology is tremendous.[2]

The joker in the last paragraph is that, in fact, relatively little is known about yield response to irrigation. This is perhaps the most important outstanding problem of fundamental research in the effective application of natural resources to agriculture. The currently accepted basis for determining quantity and timing for irrigation is potential evapotranspiration, defined[3] as "the maximum amount of evaporation that can occur from crops under given climatic conditions." More specifically, it has been suggested that:

> The evapotranspiration of a short green (crop) cover in the absence of advective energy cannot exceed the evaporation from an open water surface exposed to the same weather.
>
> Whenever soil moisture is adequate for favorable crop growth, and in the ab-

[2] Maass, Arthur, Maynard Hufschmidt, and others. Design of Water Resource Systems, (Cambridge, Harvard Univ. Press, 1962), Chaps. 11–14; Harold A. Thomas, Jr., "On the Efficient Use of High Aswan Dam for Hydropower and Irrigation," mimeo, no date.

[3] Hagan, Robert M. and Yoash Vaadia. "Principles of Irrigated Cropping," *Arid Zone Research Proceedings* (Plant-Water Relations Symposium, Madrid), 1959, p. 216.

sence of advective energy, the evapotranspiration rate is largely independent of the type of green plant cover and is determined by the weather and the extent of soil surface covered by the crop.[4]

These principles have led to conclusions such as the following:

> . . . the first step in planning efficient use of water by crops, would be to find out potential evapotranspiration in a tract and then work out how much of this need is being met by rainfall. The rainfall exceeding the soil moisture deficit is a waste. The negative differences between rainfall and potential evapotranspiration will indicate net deficiencies to be met through irrigation. . . .
>
> In use of the climatological formulae, it is assumed that the field is completely covered with vegetation and that it is in active stage of growth. For a fortnight after sowing and again at the end of maturity of crops, the climatological formulae will not apply.[5]

and:

> Our estimates for crop requirements for evapotranspiration were made by multiplying the estimated free-water surface (lake) evaporation by a "use coefficient" for each crop. The evapotranspiration requirement includes water transpired by the plants under optimum growing conditions and water evaporated from the ground surface in the fields.[6]

The fundamental defect of these applications of the potential evapotranspiration principle lies in the phrases "efficient use of water" and "optimum growing conditions." Meeting the "water requirements" of crops based on potential evapotranspiration is optimal only in two situations: first, if water is a free good – that is, in such plentiful supply that additional units would not detract from production elsewhere in the economy; and, second, if the relationship between crop-yield per unit of water and the rate of irrigation reflects increasing returns all the way up to the evapotranspiration requirement. Otherwise, potential evapotranspiration[7] is an insufficient guide to optimal irrigation procedure, for "optimal" must rightly be defined to mean maximal economic return rather than maximal physical yield.

The question of whether water is a free good can be dismissed. Central to the agricultural problem of the Indo-Pakistani subcontinent is the

[4] Perman. H. L. "Evaporation: An Introductory Survey," *Netherlands Journal of Agricultural Research.*

[5] Dastane, N. G. and Mahendra Singh. "Optimum Requirements and Utilization of Irrigation Water," Paper presented at the November, 1963, symposium on optimum requirements and utilization of water for irrigated crops, under the auspices of Central Board of Irrigation and Power, New Delhi, 1963.

[6] Harza Engineering Company International. "Supporting Studies, A Program for Water and Power Development in West Pakistan, 1963–75; An Appraisal of Resources and Potential Development," September, 1963, pp. 11–19.

[7] Hagan and Vaadia, op. cit., p. 217.

scarcity of water. The question of whether the response of crop yield to water input reflects increasing returns is empirical. Graphically, the question is whether the "production function" (as a function relating the response of outputs to inputs is called) of water has the shape depicted in Figure 1 or that in Figure 2 (page 194). In both Figure 1 and Figure 2, inputs other than water are fixed. In both figures, Q_1 represents the minimum amount of water required to sustain plant growth on one acre to maturity, and Q_3 represents the amount of water that provides the maximal physical output per acre.

Potential evapotranspiration can at best shed light on Q_3. With the exception of two periods in a crop's life cycle, the time required for a crop to grow to the point at which it covers the field and the time at the end of the growth cycle during which growth is no longer desirable, Q_3 is – according to the potential evapotranspiration theory – the same for all crops that have the same growing season. But the function $f(Q)$, shown in Figure 1, reflects increasing returns only up to Q_2 feet of water per acre. Beyond this point, the ratio of total crop output to total water input – the average yield per unit of water – declines. Hence if, for example, *unirrigated* land rather than water were free (very likely in desert areas), and if the cost of water distribution could be ignored, the optimal rate of applying water would be Q_2. The excess $(Q_3 - Q_2)$ would contribute more to total output by being transferred to other acres. If neither water nor land is free, the optimal application rate lies between Q_2 and Q_3.

If the production function has the form shown in Figure 2, the optimal application rate is Q_3, even if land is free, for the ratio of yield-per-acre to water-per-acre increases up to this point. Thus, in this case the quantity of water that provides the maximum physical yield also provides the maximum economic return.

The shape of the production function for water is therefore crucial, and its delineation ought to receive a high priority in both theoretical and applied research. All too often, research is directed simply to finding Q_3 and $f(Q_3)$.

Estimating "production functions" for water is, of course, much more complicated than Figures 1 and 2 suggest. The timing is crucial, as is the water quality, which has thus far in this discussion – quite improperly – been ignored. Moreover, the long-run relationship between irrigation and crop yields is of fundamental importance. This year's response of output to a given amount of water tells only part of the story, and most of West Pakistan, as well as parts of India, are currently wrestling with the cumulative deleterious effects of irrigation coupled with inadequate drainage.

When water is moved relatively long distances by means of canals, 40 to 50 per cent of the release of the headgate may be lost before it reaches

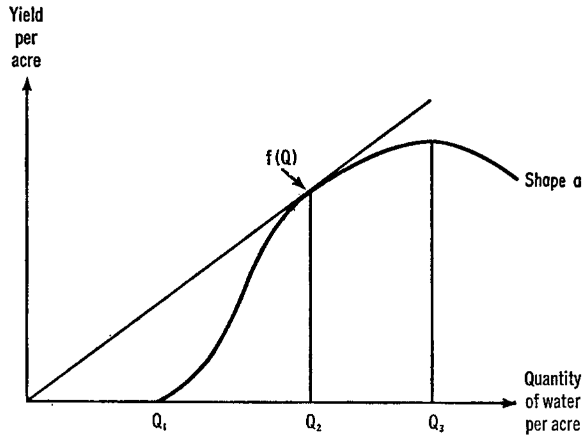

Figure 1. Response of water output to input (shape a).

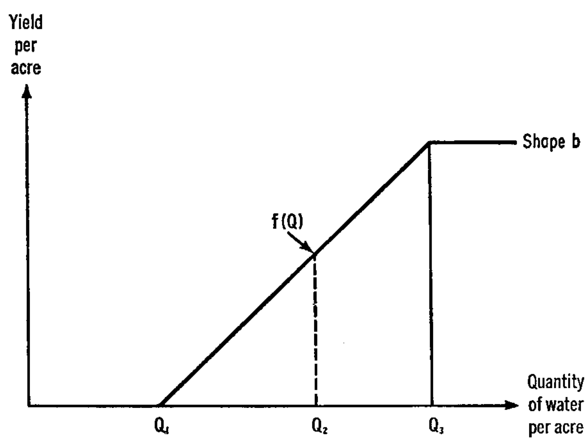

Figure 2. Response of water output to input (shape b).

farmers' fields, partly through evaporation, but largely through seepage. Some of the loss to the ground eventually finds its way to the sea, but where the seaward gradient of the land is as slight as in West Pakistan—about one foot per mile—water tends to move very slowly, and the water table rises. The rising water table limits the root zone of crops, finally making cultivation impossible.

There is a second, equally deleterious, effect. Although the rivers of West Pakistan are relatively free of salts, continued irrigation over many years must lead to accumulation of salts in the root zone of the soil unless water is applied in sufficiently large quantities to drive salts below that zone. The snow-white patches of saline soil that dot the landscape of West Pakistan are the end result of salt accumulation. Water-logging and salinity tend to go together because the rise of the water table increases the rate of capillary action that brings the salts to the surface. It has been estimated that more than 10 per cent of cultivable land in West Pakistan had been lost to production by waterlogging and salinity by the 1950s. In some districts, 40 to 50 per cent and more of the land was classified as waterlogged or saline. The reduction of yields on lands that remained in production may represent an even greater loss.[8]

The solutions to the problems of water logging and salinity are complementary. First, the economically optimal rate of irrigation must be redefined to reflect the need for leaching salts. Thus, regardless of whether the irrigation production function takes the form represented in Figure 1 or that in Figure 2, irrigation must periodically *exceed* the evapotranspiration requirement. How much and how often? These appear to be unresolved questions, but ones that surely deserve study.

Hand-in-hand with leaching of salts must be provision for drainage to prevent the water table from rising to the root zone of crops. Drainage need not represent only additional outlays. Aquifers of sufficiently good quality can be used to supplement canal supplies in the general irrigation program, as well as to leach saline soils to restore the land to production.

The over-all conclusion that emerges from the experience of West Pakistan is that surface water and groundwater must be managed jointly. Management of ground and surface supplies is a prime instance of a systems problem that requires the combined effort of specialists from many disciplines if it is to be solved. To plan separately for canal irrigation, groundwater pumping, and drainage is at best to guarantee inefficiency and at worst to invite disaster.

A host of problems invites the application of modern science and technology. First is the choice among alternative methods of groundwater management, posed by Dorfman, Revelle, and Thomas as a choice between alternative combinations of "vertical" drainage—that is, pumping of ground water by means of tube wells—and "horizontal" drainage, or export of water by means of surface drains.[9] Where the groundwater is of sufficiently high quality, vertical drainage can be used to supplement surface water, an important advantage when timely water is in as short supply

[8] The White House Department of the Interior Panel on Waterlogging and Salinity in West Pakistan. "Report on Land and Water Development in the Indus Plain," Washington, The White House, January, 1964 ("The Revelle Report"), p. 83.

[9] Dorfman, Robert, Roger Revelle, and Harold Thomas, "Waterlogging and Salinity in the Indus Plain: Some Basic Considerations," *The Pakistan Development Review*, Karachi, Autumn Vol. 5, 1965, pp. 354 ff.

as in most of the subcontinent. However, horizontal drainage may be necessary to export low-quality waters unfit for irrigation. Even when the water table is well below the root zone and well below the depth at which gravity drains are necessary or even useful, it may be necessary to pump low-quality pools when they are interspersed with pools of high-quality water, simply to prevent contamination of the latter. In choosing a mix of vertical and horizontal drainage, the critical variable is the quality configuration of the groundwater.

This raises a second problem – the very definition of water quality. Quality cannot be measured by a simple count of parts of dissolved salts per million parts of water. The composition of salts and other compounds in the water, as well as their quantity, determines its fitness for irrigation.[10] Water of a given quality, moreover, may be suitable for one soil but unfit for another. The continuing disagreement among experts about the dimensions of water quality indicates the need for continuing research in this area.[11] Yet there would seem to be no doubt that large quantities of groundwater can be used in mixtures with surface water to augment total supplies.

A third set of issues that must be mentioned are technical problems associated with drainage. One is the need for research on inexpensive means of sealing canals to prevent the percolation of water that creates the drainage problem in the first place. A related need exists for the development and application of a suitable technology in the prevention of evaporation, particularly in large reservoirs. A second consideration is well design. Screens must be provided to prevent infiltration of sand. At present, the choice lies between cheap screens that must be replaced frequently and expensive screens that are durable. An inexpensive but durable screen would reduce the cost of groundwater appreciably.

Despite the disagreements among experts with respect to specifics,

[10] Maasland, M., J. E. Priest, and M. S. Malik, "Development of Groundwater in the Indus Plains," Paper presented to the symposium on waterlogging and salinity in West Pakistan, Lahore, October, 1963; also Dorfman, Revelle, and Thomas, op. cit., pp. 343 ff.

[11] The following indicate the scope of the problem: Report on Land and Water Development in the Indus Plain, The White House Department of Interior Panel of Waterlogging and Salinity in West Pakistan, January, 1964; Diagnosis and Improvement of Saline and Alkali Soils (Agriculture Handbook No. 60, United States Department of Agriculture); Maasland, Priest, and Malik, op. cit.; C. A. Bower and M. Maasland, "Sodium Hazard of Punjab Ground Waters," paper presented at symposium on waterlogging and salinity in West Pakistan, Lahore, October, 1963 Ghulam Mohammad, "Waterlogging and Salinity in the Indus Plain: A Critical Analysis of Some of the Major Conclusions of the Revelle Report," *The Pakistan Development Review*, Karachi, Autumn 1965, Vol. IV, No. 3; Dorfman, Revelle, and Thomas, op. cit.; N. Ahmad, "Comment," F. Eaton, "Comment," and G. Mohammad, "Rejoinder," *The Pakistan Development Review*, Autumn 1965, Vol. V, No. 3.

West Pakistan has recognized the need to integrate the planning and development of surface and groundwaters within the entire Indus River Basin. In response to this recognition, the data required for integrated planning—surveys of groundwater depths and qualities, surface run-offs, and so on—have been collected and are continually supplemented. Presumably because the problems of waterlogging and salinity have never been so pressing in India, much less has been done to integrate such planning there. Thus far, even the aquifer that lies under only about 10 per cent of the cultivated acreage in India has barely been surveyed. Up to 1964, 67,500 square miles had been explored under a survey program begun ten years earlier. Only 568 boreholes had been drilled, a ratio of less than one borehole per 100 square miles, which hardly seems adequate for a systematic survey.[12]

A similar situation exists with respect to surface water supplies. Detailed, up-to-date calculations underlie the estimates of present utilization of 83.5 million acre-feet (MAF), utilization of 92 MAF by 1975, and ultimate utilization of 120 MAF of the 140 MAF of annual flow that are available for exploitation by West Pakistan.[13] The only estimate of surface water supplies in India, on the other hand, is a crude survey dating from 1950, and this has served as the starting point for all subsequent calculations.[14] Of 1,350 MAF total annual run-off, the round figure of 450 MAF, or one-third, has been taken as the ultimate exploitable quantity.[15] (Current utilization is 150 MAF.) Of course, the problems of estimating surface water supplies in the myriad river systems of India, with its wide variety of climatic conditions, are formidable, but this would seem to be a reason for beginning today, not tomorrow.

Prerequisites to systematic water-resources planning in India are, first, intensification of the ground and surface water surveys and, second, the integration of groundwater and surface water development planning on a basin-wide basis. The planning dichotomy between major and medium projects and minor projects (the cut coming at a capital cost of Rs 1,000,000 or about $210,000 at pre-June 1966 devaluation exchange rates) and division of responsibility between the Irrigation and Power Ministry (major and medium projects) and the Food and Agriculture Ministry (minor projects), not to mention the division of responsibility between the central government and the states, would hardly seem conducive to good results.

[12] Government of India, Ministry of Food and Agriculture, Department of Agriculture, "Report of the Working Group for Formulation of Fourth Five Year Plan Proposals on Minor Irrigation," New Delhi, Chap. 16, mimeo, no date.

[13] Harza Engineering Company International, "Program for Water and Power Development in West Pakistan through 1975 (Master Plan—Initial Phase)," Lahore, 1964.

[14] Government of India, "Report of the Working Group for Formulation of Fourth Five Year Plan Proposals on Minor Irrigation," op. cit., pp. 32–33.

[15] Government of India, Planning Commission, *Third Five-Year Plan*, New Delhi, p. 380.

I have emphasized the complementarity of the development of water resources below and above the surface of the ground, but irrigation planning cannot be separated from other aspects of planning for agricultural development. A chief lesson of the "Revelle Report"[16] was that isolated development of water resources in West Pakistan would be a dubious economic venture at best. However, development of water resources in conjunction with expansion of the use of fertilizers, pesticides, improved seeds, and other factors was estimated to promise returns far in excess of costs. This "principle of interaction" – the superadditivity of the contributions of components – is a cornerstone of all agricultural science and is well known to every farmer.

It has already been noted that the position of the production function for water, as pictured in Figures 1 and 2, depends on the levels of application of other inputs, like fertilizers and pesticides. Superadditivity of the contributions of inputs to output means that the slope $f'(Q)$ as well as the level $f(Q)$ depends upon the levels of inputs other than water. Recall the Dhabi cultivator who hesitated to use fertilizer partly because of uncertainty about water deliveries. The implications for planning and research are obvious. Research, planning, and implementation must all involve specialists in each aspect of agricultural development.

In irrigation, as in all areas of development planning, technical problems must always be viewed as economic problems – as a choice among *alternative* means of accomplishing goals. Consider the peremptory dismissal of economics by the authors of the master plan for the development of the Indus Basin:

> The large investment in the IBP [Indus Basin Project] has been made necessary by events over which Pakistan has no control. As an essential replacement project, the IBP as a whole is not amenable to economic evaluation.[17]

Resources have alternative uses, and "essential" is, economically, a relative term. Even taking so narrow a goal as a specific level of irrigation development, there are choices to be made. For instance, the operating costs per acre foot of water delivered by large-scale storage systems are a negligible fraction of capital outlays, say 1 per cent, and surface storage systems typically may serve fifty, one hundred, or more years. Tube wells, on the other hand, entail operating costs of the order of 20 per cent of capital costs and require replacement every twenty years. Hence the rate of interest used to place future operating costs and present capital costs on a common footing becomes a critical determinant of the least-cost means of providing water.

[16] Op. cit.

[17] "Program for Water and Power Development in West Pakistan through 1975," op. cit.

The goal of development of water supplies is itself all too narrow. Water is a means to the end of agricultural production, and agricultural production is a means to income and the material satisfactions of life. Thus, choices must be made between agriculture and other means of increasing incomes, specifically industry.

There is a second problem. The principle of interaction suggests that within agriculture it will often be optimal, from the point of view of maximizing income, to concentrate limited resources – such as water, fertilizers, and agricultural extension personnel – in a limited area and with a limited number of farmers. This raises a second objective to be set alongside the objective of maximizing income – ensuring a fair distribution of the returns from public contributions to economic development.

Were it possible to rely on the tax system to transfer income from the original gainers to the rest of the population, and were it not for the need to provide relatively large material incentives to ensure the rapid adoption of a new technology, the distribution question could be divorced from the income-maximization question in economic planning. Any portion of income gains could be extracted from the original gainers and transferred to the rest of the community. But because of the weakness of the Indian and Pakistani tax systems and because of the need to provide incentives, questions of income size and distribution become inexorably intertwined. Many politicians sense this intuitively, even if some economists insist on keeping their heads in the sand. To ignore the division of the economic pie in the design of water-resources development programs risks irrelevance every bit as much as would disregard of the size of the pie.[18,19]

[18] For methods of coping with multiple objectives – for example, improving the balance of payments, increasing national income, and improving its distribution – *see* Stephen A. Marglin. Public Investment Criteria (London and Cambridge, Mass: George Allen & Unwin and Massachusetts Institute of Technology Press, 1967).

[19] I am indebted to my colleagues Walter Falcon and Harold A. Thomas, Jr., for discussions of the issues treated in this paper. Much as I might like to, it would be foolhardy as well as unjust to attempt to shift the blame for any lack of appreciation and understanding of their observations on my part.

SOME STATISTICS ON IRRIGATION PLANNING

TABLE I

Arable and Irrigated Area

	Net sown acreage (million acres)	*Net irrigated acreage (million acres)*	*Irrigated as percentage of sown acreage*
United States	470 (1960)	33 (1959)	7
India	326 (1958–59)	58 (1958–59)	18
West Pakistan	42 (1962–63)	32 (1962–63)	71

Sources: For U. S.: *FAO Production Yearbook, 1961, Rome;* For India: *Statistical Abstract of the Indian Union, 1962,* New Delhi; For West Pakistan: Harza Engineering Company International, *Program for Water and Power Development through 1975* (*Master Plan—Initial Phase*), Lahore, 1964.

TABLE II

West Pakistan: Public Sector Expenditures on Water Resource Development (Excluding Power)

Expenditure (*Rs million*)	
Second Five Year Plan (1961–1965)	870
Third Five Year Plan (1966–1970)	2,270

Sources: Government of Pakistan: *Second Five-Year Plan,* Karachi, June, 1960; *Third Five-Year Plan,* Karachi, May, 1965.

TABLE III

West Pakistan: Irrigation in the Indus Plain by Source

	Surface water (million acre feet per year)	*Ground water (million acre feet per year)*	*Total (million acre feet per year)*
1963	83.5	2.0	85.5
1975	92.1	26.9	119.0
Ultimate	120.3	40.0	160.3

Source: Harza Engineering Company International, *Program for Water and Power Development through 1975* (*Master Plan—Initial phase*), Lahore, 1964.

Comment: Harza Engineering Company International estimates costs of water and power development for 1975 at Rs 21,000 million. The foreign exchange costs of the Indus Basin Project portion of this total, Rs 5,740 million, will be covered by grants and loans from the Indus Basin Development Fund.

TABLE IV

India: Irrigation—by Size of Scheme

(in million acres—gross)

	Minor schemes	*Major and medium schemes*	*Total*
1950–51	36	20	56
1960–61	43	28	71
1965–66	50	36	86
1970–71	59	47	106

Major schemes: Capital costs exceed Rs 50 million.

Medium schemes: Capital costs exceed Rs 1 million but less than Rs 50 million.

Minor schemes: Capital costs less than Rs 1 million.

Sources: Government of India: Planning Commission, *Third Five-Year Plan*, New Delhi; Planning Commission, "Memorandum on Fourth Five-Year Plan." New Delhi, October, 1966; Ministry of Food and Agriculture, Department of Agriculture "Report of the Working Group on Formulation of Fourth Plan Proposals for Minor Irrigation," New Delhi, mimeograph, no date.

TABLE V

India: Irrigation by Type of Scheme
(in million acres—net)

	Government Canals	*Private Canals*	*Tanks (Ponds)*	*Wells*	*Other Sources*	*Total*
1958–59	21	3	12	16.5	5.5	58

Source: *Statistical Abstract of the Indian Union, 1962,* New Delhi.

Comment: The discrepancy between the total of 58 million acres and the figure of 71 million acres for 1960–61 in the previous Table arises, first, from double-cropped acreage (the difference between gross and net); second, from the growth in irrigated acreage between 1958–59 and 1960–61; and, third, by differences in the estimating procedures of various agencies, differences recognized by Indian authorities but not resolved (the figures of Table 4 for minor irrigation, and hence the totals, may well be on the high side).

TABLE VI

India: Expenditure of Central Government on Water-Resources Development
(Exclusive of power)—by Size of Scheme
(in Rs millions, current prices)

	Minor schemes	*Medium and major schemes*	*Total*
First and Second Plans (1951 to 1960)	1,850	6,700	8,550
Third Plan (1961 to 1965)	1,750	5,500	7,250
Fourth Plan (1966 to 1970)	4,500	8,750	13,250

Sources: Government of India: Planning Commission, *Third Five-Year Plan,* New Delhi; "Memorandum on Fourth Five-Year Plan," New Delhi, October, 1964; Ministry of Food and Agriculture, Department of Agriculture, "Report of Working Group for Formulation of Fourth Five-Year Plan Proposals on Minor Irrigation," New Delhi, mimeograph, no date.

Comment: Expenditures on irrigation during the first three plan periods averaged about one per cent of gross national product.

TABLE VII

India: Medium and Major Irrigation Developments and Costs

	Gross additional area—potential (million acres)	*Gross additional area—actual utilization (million acres)*	*Additional annual water utilization (million acre feet per year)*	*Capital expenditure (Rs million)*
First and Second Plans	11.7	8.3	43	6,700
Third Plan	8.3	7.7	41	5,500
Fourth Plan	14.0	11.0	50	8,750
	Additional water per additional acre—actual utilization at canal headgates (feet per year)	*Additional water per additional acre—actual utilization on farm* (feet per year)*	*Capital expenditure per additional acre—actual utilization (Rs)*	*Capital expenditure per additional annual acre-foot of water on farm (Rs)*
First and Second Plans	5.2	2.6	805	312
Third Plan	5.32	2.16	715	268
Fourth Plan	4.95	2.48	795	350

*) Assuming canal losses of 50 per cent

Sources: Government of India: Planning Commission, *Third Five-Year Plan,* New Delhi; Planning Commission, "Memorandum on Fourth Five-Year Plan," New Delhi, October, 1964; Central Water and Power Commission (for estimates of column 3).

Comment: Without considering amortization and operating costs, the actual cost of canal water depends only on the rate of interest. Take the round figure of Rs 300 as the capital cost of one acre-foot of irrigation per year delivered to the farm. The implied relationship between the average cost of canal irrigation supplies developed since the commencement of the First Five-Year Plan and the interest rate is given below:

Interest Rate	*Average cost per acre-foot*
5%	Rs 15
10%	Rs 30
15%	Rs 45
20%	Rs 60

Water Resources Development in Pakistan and India

OLIVER H. FOLSOM

IN THE SOUTH ASIAN SUBCONTINENT the range of climate, including rainfall, is as varied as anywhere in the world. At one extreme—in the Rajasthan desert of India and the desert of West Pakistan—there is virtually no rainfall. At the other extreme, over 600 inches per year fall at Cherrapunji in Assam.

The subcontinent is crowned by the world's greatest mountain range, which is the spawning ground of most of the great rivers of South Asia. The Himalayas are particularly noted for one area in southwestern Tibet from which spring the Indus, Sutlej, Jumna, Ganges, and Brahmaputra rivers. They flow in different directions, but all furnish water for life on the great plains of Pakistan and India. There was a time (according to ruins of cities and irrigation works, probably not more than 3,000 years ago) when the Indus, Sutlej, Jumna, and Ganges emptied into the Arabian Sea. Now both the Jumna and the Ganges flow to the east into the Bay of Bengal. It is believed that, as the result of seismic movement, much more Himalayan water is now flowing in the Brahmaputra than in the Indus.

Water resources do not respect national boundaries, especially those that are the result of political agreements. The waters in the Indus basin in India and Pakistan are no exception. When the countries were partitioned in 1947, the control and use of the waters of the Sutlej, Beas, Ravi, Chenab, and Jhelum Rivers in Punjab were disputed, as were large irrigation works already constructed.

This resulted in the 1960 Indus Agreement between Pakistan and India. Under the agreement, India was given control and use of all the waters in the Sutlej, Ravi, and Beas rivers, and Pakistan was given the right to use

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and control the Chenab, Jhelum, and Indus, except for a small amount used in Jammu and Kashmir. The agreement also included plans and financing for the necessary construction of storage and link canals to serve properly the lands of Pakistan that had previously drawn water from the eastern rivers now controlled by India. At the same time it allowed India to forge ahead on its plans to irrigate some three million acres of Rajasthan and strengthen the irrigation of the Indian Punjab.

Mangla, the main storage dam on the Jhelum River, is virtually completed and the link canals are almost finished, so that Pakistan is independent of Indian withdrawals from the three eastern rivers. Additional plans are also afoot. More storage area is proposed at Tarbella on the Indus, and additional canals and laterals are being considered to utilize all surface water.

Underground water in West Pakistan has become a double-edged sword. Its development has been sensational in the last six years. It has been used to lower the groundwater table in the areas of old Punjab that have become waterlogged, and also to supplement the available surface water for irrigation. Tube wells by the thousands have been drilled – the first by government agencies and others, in the last few years, by the private farmer, who has at long last come to realize the great value such irrigation has to offer.

Paradoxically, East Pakistan is one place where there is, if anything, too much water. During monsoon season, water covers as much as half of the province, the result of the confluence of the Ganges, Brahmaputra, and Meghna rivers at flood. Their total maximum flood flow has been estimated at as much as 7 million cubic feet per second (cusec).

However, the monsoon is an unreliable lady. The Aus (or early) crops are in critical trouble if the monsoon is late; the Aman (somewhat later) crops suffer if it finishes early. It has been found that irrigation for either crop will increase production as much as 100 per cent and, of course, a boro (spring rice) crop is not possible without irrigation during the dry winter. Even with as much as 100 inches of annual rainfall, irrigation is required if the possibility of producing food and fiber sufficient for the needs of East Pakistan's 55 million people is to be realized. At present, most of the irrigation water comes from the rivers. There are several large projects – such as the Ganges-Kobadack Project, Teesta Project, and Dacca-Demrya Project – that are in partial operation, and many smaller low-lift types of projects are now being used on limited lengths of canals. A fairly recent development has been the private use of pumps (two to three cusec capacity), many of which are owned outright by individual farmers or are rented from the Agriculture Development Corporation.

Another facet of irrigation in East Pakistan is the use of groundwater.

It is present almost everywhere and apparently in good quantities fairly near the surface. A well-designed grid of conventional tube wells, electrically powered, has been installed in the Thakurgaon area of northwest East Pakistan. Each well is connected to a canal, and the system was used for the first time about three years ago (some 300 wells) with some indications of success. Private farmers in East Pakistan who are too far from the rivers are also starting to install tube wells. In general, irrigation is taking hold, confounding many experts in water resources development who have come to believe over the years that any area with more than 40 inches of rain per year is not susceptible to irrigation.

India is also at the mercy of the monsoon, and the present food shortage may be laid at the door of a "poor monsoon" and not enough irrigation. We have already discussed the three eastern rivers of the Indus (Sutlej, Ravi, Beas) and their irrigation of Punjab and Rajasthan. Almost every state of India has partially harnessed its larger rivers and is working as quickly as possible toward fuller utilization. A brief roundup of the situation would reflect these circumstances. The Jumuna River irrigates Punjab and Uttar Pradesh; the Ganges River serves Uttar Pradesh, Bihar, and West Bengal; the Chambal River irrigates Rajasthan and Madhya Pradesh; the Gandak, Kosi, and Sone rivers are used in Bihar; Damodar River irrigates West Bengal; the Tapti, Mahi, and Narmada rivers irrigate Gujarat; the Mahanadi River irrigates in Orissa; the Godavari River irrigates in Maharashtra and Andhra Pradesh; and the Kristna River irrigates in Maharashtra, Mysore, and Andhra Pradesh.

Groundwater in India, particularly in the Ganges plain, has been used for centuries, but has been retrieved only by Persian waterwheels, weighted buckets, and bullock haul. Modern India installed several thousand tube wells with pumps in Punjab, Uttar Pradesh, and Bihar during the 1950s, drilled 350 exploratory wells in such places as Assam, West Bengal, Rajasthan, Orissa, Madras, and Kerala, and fitted many dug wells with modern pumps. A preliminary report was prepared in 1959 on the performance of some of these wells. Considerable private well drilling has been going on since that time, but the full potential of groundwater has neither been utilized or explored.

It has been said that the Moghuls began irrigation in the subcontinent sometime in the sixteenth century. Certainly India under the British took it up over 150 years ago. The construction of the Ganges canal in Uttar Pradesh about 110 years ago was undoubtedly preceded by works on the Indus River. At the turn of this century, the Indians were considered the most experienced large irrigators in the world, and the United States government consulted them when forming its own Bureau of Reclamation.

As admiring as we were at the turn of the century, the science of irrigation has since developed so extensively that we now think we know many of the answers regarding waterlogging and salinity, which have cursed and actually destroyed civilizations in our past history. Mesopotamia is perhaps the best-known example. In both East and West Punjab millions of acres of land have been taken out of production because of these twin curses. In fact, it has been suggested that the cheapest way to irrigate large areas of land in Pakistan and India today may not be to build additional multiple-purpose projects but simply to rehabilitate the millions of waterlogged and salinized acres.

Much of this trouble could have been prevented and should certainly be prevented in the future. The causes are many: types of soil, lack of drainage, underground geology, artificial barriers on the surface, leaking canals, too much irrigation, too little irrigation, and high salt content. Many of the evils can be corrected by establishing proper underground drainage and using enough irrigation water to leach salts out of the land.

I have said irrigation is a science; it is also expensive and hard work. It calls into play all the skills of modern farming, which must be used properly to take advantage of water availability. Irrigation and fertilizers go hand in hand. Water is essential for realizing the full value of fertilizers, and vice versa. The present emphasis on fertilizers to increase production must be tempered with the knowledge that several inputs are necessary – water, seeds, and proper cultivation – to get the increased yields that are often credited to fertilizers alone.

One of the major mistakes in irrigation on the subcontinent has been the insistence of local engineers on allocating irrigation water at the rate of one foot per acre per year. This is not enough in the lower rainfall areas and, in fact, is a principal cause of salinity. One consulting team sent to India in the 1950s reported that it would be possible to grow more on five acres with four feet of water than on twenty acres with one foot of water. Irrigation is not based only on the amount of water but also on the rate of application. Works should be designed with this in mind. Unfortunately, prior to 1960, engineers in the subcontinent did not do this, hence it is now difficult to take advantage of recently developed irrigation techniques.

As irrigation is technical and complicated, so is the climate and the society it produces. If properly used, it takes the farmer out of his marginal, subsistence existence and creates a demand for many items not previously needed or even considered. It places a burden on the respective governments to furnish agricultural extension services; engineering for land leveling and farm ditches; price supports – or, at a minimum, a more stable market; proper agricultural loan facilities; farm-to-market roads; power facilities; public or private storage capacities; and cooperative patterns of operation.

In conclusion, it is fair to state that something less than 50 per cent of the water resources of the subcontinent is in use today; the percentage of groundwater used is much less. As the drive gets under way to use water more fully, it should be remembered that the actual physical use of water, while all-important, is really only a small part in the development of agricultural productivity. The governments, institutions, and private individuals concerned must create the services and infrastructure needed to support present irrigation and to get from it its maximum value. At the same time, we must collect data, plan, and otherwise prepare for the further use of water for irrigation. If this is done on the modern level, using modern methods, the eventual maximum use of all the available water resources in India and Pakistan should be assured.

5

AFTERWORD

The Way for the Will

STEVAN DEDIJER

"We have fallen behind the advanced countries by as much as fifty to one hundred years. We have to overcome this lag within ten years. Either we accomplish this, or we perish."
JOSEPH STALIN, *Pravda*, 5 February 1931

"Ours is a culturally undeveloped country."
MAO TSE TUNG, 1957

NO MATTER where in the world they are held, conferences that produce books such as this one tend to end with papers on "the future of" the major area of interest with which they deal. This is not just the latest fashionable manifestation of the basic and specific trait that man has always had, and that no other animal seems to have—a preoccupation with his social future, accompanied by attempts to guess that future and to influence it by incantations and actions. Rather, such preoccupation is a reflection of the radical change, occurring before our eyes, in the attitude of men everywhere to the manageability of the future. All of us are rapidly learning that today the future of a society can no longer just be guessed at. Much more than at any time in the past, the future actually can be engineered.

The causes of this altered attitude are too complex even to be listed and related to each other in a short essay. I shall only advance the hypothesis that scientific change is bringing about and influencing social change, giving it direction and making it irreversible at all levels. Social striving after possible goals is, in effect, the striving after the "good life." This is no longer purely a philosophical or even a religious problem. It has become a political problem, a social force that is moving the broadest section of the population in every country.

An analysis of the basic statements of goals and objectives of political parties and governments shows that all of them are, in a great variety of

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ways, striving to achieve mass-society goals. This is true of the United States and China, India and the USSR, the United Kingdom and France, and many dozens of others—large and small, developed and underdeveloped, so-called "Communist" and so-called "capitalist." These are societies in which the material conditions of life for work, for education, health, and security, and for the development of the creative abilities of the individual citizen are sought for all, regardless of class, sex, race, or nationality.

Up to the present, the planning of social development in these countries has been limited to the planned change of their material cultures. These plans involve alterations of productive forces, technology, industry, and agriculture. They include education of labor, improvement of health, and so on. But as is increasingly realized, the effective pursuit of development goals must also embrace social systems, values, and beliefs. Inevitably, this means changes in social institutions, from the family and the political system to religion and education. It calls for drastic changes in structures, functions, norms, habits, and customs of the country. It also requires changes in the basic attitudes of individuals and institutions toward the world of nature, toward society, and toward individuals who make up this society at national and world levels.

A national will to develop is the first prerequisite if the "good life" is to be realized. Where that will exists, where it is fostered and institutionalized, where it is organized and expressed in the attitudes of millions of individuals living in particular countries, science—social and natural, basic and applied—will point the way.

The active pursuit and planning for mass-society goals has become possible because of the growth of the power of science. Looking at the past, we note that Bacon's brilliant conjecture of 350 years ago—"science is power"—remained for a long time *only* a brilliant conjecture. Two hundred years after Bacon, Condorcet also could only hope that science—basic and applied—would become a major power for the improvement of human life. Yet, during only the past two generations, science has become a major social power, both relatively and absolutely.

Research and development, which are the active elements, the productive subsystems, of science have become the latest major categories in the division of human labor. As students of social science have shown, the growth of inventions and discoveries and the resulting social innovations are taking place at an exponential rate. During the recent past, the world has invested more in R and D, produced more R and D personnel, and achieved more research results than during all the past generations of human history put together. In the next ten to fifteen years more people in the most developed countries will be employed in R and D and in the production of manpower for R and D, than in the production of food.

Recognition of the need to develop science as an essential element in the drive to modernization occurred in Japan and the Soviet Union at the very beginning of radical political changes that brought into power elites with a strong will to modernize. While these countries followed different paths, the need for scientific and technological development was powerful in both and was the key element in the ideologies of the new leaderships.

This will is found in all the major countries of the world today. More than one government leader in the United States and more than one basic science policy document produced by the executive and legislative branches of its government have stressed that a major goal of the United States is to keep a leading position in all the key branches of science and to use science for the achievement of economic, social, and political objectives of the country. The program of the Bolshevik Party of the Soviet Union repeats, in almost the same words, that their major objective is to achieve leadership in all the key sectors of science—basic and applied, natural and social. In present-day China, leaders such as Chou En Lai, Mao Tse Tung, Lin Piao, and others have, ever since they came into power, reiterated that one of their major national objectives is to catch up scientifically with the most advanced countries.

Some underdeveloped countries, such as India, China, and Pakistan, have proud, ancient cultures, which, from the point of view of the present aims of mass societies, remain underdeveloped in the material and social sense. These must realize that they may never achieve the scientific goals they have set for themselves unless they develop a national will, expressed by political forces. Of course, all countries cannot be first in all fields of scientific and technological endeavor. It is vital that each seek a level of development that is consonant with scientific progress elsewhere in the world and, at the same time, is proportionate to its own size and resources.

This necessity to develop a strong national will, expressed in policies, plans, and actions to implement them, is especially urgent in the light of the present worldwide state of scientific development. The melancholy fact is that, in the world today, there is a most uneven distribution of effort. Indeed, most of the world consists of a virtual research desert: 25 countries, with only 25 per cent of the world's population, have between 80 to 90 per cent of the world's research manpower. These same countries spend more than four-fifths of the world's research funds, and have close to 90 per cent—and, in some instances, 100 per cent—of the world's research equipment and facilities. The other 130 countries, which contain close to three-fourths of the world's population, have less than 10 per cent of the research potential and produce less than one tenth of the inventions and discoveries, as measured by such indicators as science and technology papers.

The strength of the will to develop science in a country, one can say, must be in direct relation to the degree it lags behind developed countries that are comparable in size. The United States spends an equivalent of 14 days of its yearly wealth and services on the production of scientific knowledge. India's total research expenditure has just reached about $100,000,000, equal to the research budget of a single large United States' company such as General Electric. This is equivalent to the yearly expenditure of less than a quarter day of the wealth and services produced by the entire population of India. If India does not consciously develop policies that will close this kind of gap, its objectives in industry, agriculture, and other fields of national endeavor will be difficult to achieve.

The problems confronting the development and use of science in India and Pakistan are further compounded by the imbalance in the distribution of their research efforts. Most of the research potential of the developed countries lies within three major institutions of society: universities, industry, and agriculture. In countries like India and Pakistan, to the contrary, most of the current research activity is outside these three sectors, concentrated in government. To reverse distribution of research resources and the products of research will require a greater effort and will be more difficult to achieve the longer the present situation is allowed to continue.

The planned change of societies is extremely complex. Social sciences are producing evidence, based on practical experience, that it is even more complex than had been realized. When we look at the last hundred years of social evolution in the most developed countries, we can see that today they are radically different from what they were one hundred years ago. In most cases, their social organisms evolved without planning. However, as I mentioned earlier, Japan and the Soviet Union are exceptions—their social evolution has been the result of careful, far-sighted policy changes, and each has achieved goals many outsiders felt would be impossible.

The future of science in India and Pakistan will be what their present leadership wills it to be. First, these countries must be willing to accept an "impossible" goal—that they will become leaders in scientific endeavors most suited to their own needs. This is a precondition not only for the development of their science but also for their social development.

Second, armed with such will, the leadership must build centers for continually producing information about the problems that face them in the period of their most rapid evolution. Social sciences must provide a mirror in which can be seen an accurate and detailed image of the key areas that need change and plans for change. I myself came from Yugoslavia, a relatively underdeveloped country, so, in the social science courses I give at Lund University, I continually stress that an underdeveloped country is one with undeveloped material and social culture and systems of values and beliefs. Everything inherited from the past must be revised—and revised rapidly.

The third condition is to establish and maintain free exchange of information. This is essential to create the proper atmosphere for investigation in all areas of culture—material and social (including political), as well as values and beliefs. The development and use of science can proceed at a rapid and an efficient rate only if all the barriers that stand in the way of such development are clearly perceived. Science is a subsystem in the modern social system. Its effective expansion depends on understanding the socio-psychological barriers that exist within a traditional culture and prevent acceptance of the twentieth-century scientific tradition.

It would have been possible to paint a rosy picture of the future of science and its use for social goals in South Asia. But essentially the future of science there will be what the South Asians—and, above all, their leaders—will it to be, and how and to what an extent they use this will to develop social sciences that can show them the most effective way toward their national goals.

Science, Human Progress, and International Understanding in South Asia

DONALD F. HORNIG

IN ALL COUNTRIES, including the United States, science represents a range of activities from the purely theoretical, abstract, and intellectual to the most practical and applied. A highly critical problem is that throughout this spectrum each layer must be in effective communication with the next. Furthermore, if science is to be supported by people – and today science is supported by the taxpayers in all countries – it must ally itself with industrial development, health, and agriculture for the general welfare of the society. Otherwise it will not be supported and cannot expect to be. In many ways, this is the central problem confronting science in India and Pakistan – how to become more effectively harnessed to achievements in human progress.

It is my impression that scientists in universities in the subcontinent have a somewhat exaggerated notion of the proportion of effort the United States devotes to pure science. In fact, only about 8 per cent of American research is in pure science. I also have the impression that in both India and Pakistan the effort, while magnificent and growing, represents a smaller part of the total national effort than I would think desirable in a rapidly developing situation.

The United States government hopes – and the major purpose of my brief visit to India and Pakistan in April 1966 was to further the fulfillment of this hope – to collaborate more closely with all branches of science in India and Pakistan to our mutual advantage. It is sad that two countries which have so many problems in common should collaborate with the United States rather than directly with each other. It is worth re-

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membering that in the 1920s and 1930s—well before the United States had recognized the government of the Soviet Union—effective contact between the two countries began with interuniversity library programs. I believe that Brown University started a library exchange agreement with the University of Moscow in 1931. Individual American and Soviet scientists soon established contact through a variety of channels. The fact is that science is worldwide and scientists everywhere speak easily to each other in a common language, so their associations often long precede the resolution of political difficulties. I am convinced that the scientific communities of the United States and China will begin an effective discussion, a dialogue, long before political solutions are achieved.

Science, through the common language of ideas, can contribute not only understanding but practical advantages, and I would commend this notion to scientists in India and Pakistan. I hope that, as a result of meetings and conferences such as the symposium on which this volume is based, they will find ways to cooperate. I volunteer the services of my office, either officially or informally, to begin to arrange fruitful contacts. The two countries have so many problems in common—development of the Indus or Brahmaputra basins, health research, and many others—that there should be active collaboration between them.

Let me make one or two other observations, again precariously based on very short exposure. When resources are scarce, allocation—and planning for it—is necessary. However, in working on broadening the base of the total educational and scientific endeavor, in expanding the number of schools, colleges, and research institutions, and in securing adequate personnel, it is crucial not to lose sight of the importance of having some outstanding centers that can set standards of performance for the entire system and can provide the teachers, the researchers, the engineers, and the technicians who are needed in other institutions. In the United States, for example, 2,000 colleges and 150 universities grant the doctoral degree, but half of all academic research is done in 15 institutions. This is not necessarily a model for anyone, but I regard as almost axiomatic that, in order to move back the frontiers of knowledge in the twentieth century, a great part of the endeavor must be concentrated in relatively few centers of excellence.

The other point I would like to make in terms of planning is the importance of the talented, gifted, motivated individual who has the enterprise, the organizational ability, and the plain "push" to get things done. There are such people in Pakistan and India. It seems to me one must be most careful to avoid the pitfall of planning science and scientific development by fitting people into organizational schemes rather than by organizing schemes around the talented individuals who are the guiding lights to the future in any country. This proposition is well known to every scientist. In India and Pakistan, perhaps because resources are scarcer than in the United States, there is some tendency to bypass the power of the imaginative, creative, and enterprising individual in favor of reliance on over-all formal planning.

I am impressed that so many scientific developments in India and Pakistan are moving forward. Agricultural productivity is beginning to increase in both countries. There are even greater possibilities in the groundwater reserves in the Gangetic plain, although the lack of sufficient hydrological studies to establish adequately the extent of the resources obviously leaves important tasks ahead.

In India I had the great pleasure of talking with people about experimentation in scientific education, and was pleased to find excitement over the idea that education itself is a matter with which one can experiment. The lessons Americans have learned about science teaching may not be useful to anyone else, but it is significant that we have begun, and only begun, to learn that in education, as in science itself, one should devote at least one per cent of the effort to conscious attempts to experiment in a fundamental way, as well as to develop new curricula and new laboratory experiments. The goal is not to replace an old orthodoxy with a new one, which has been the characteristic of educational improvement in our country until now, but systematically to try new experiments in curricula, to develop new laboratory experiments, to use them in the schools, and, if they fail, to throw them away and start over again.

In these efforts there is an analogy to medicine. There, for centuries, progress occurred through isolated efforts of individual doctors. A major change took place when we realized that progress came faster by concentrating our efforts in centers like The Rockefeller University, where a relatively few scientists could carry on research so that all practitioners could use their results. In this way, progress was much accelerated. I think the same general principle can be applied to education. It was exciting to find these same ideas stirring in India, and while I was there we came to a general agreement as to ways the United States could work with India in accelerating educational experiments. In Pakistan we agreed on ways in which the United States might assist in a number of areas, particularly in family planning, public health, and rural medicine.

The tasks ahead in South Asia will require the cooperation of us all, and I would like to make a plea for the spirit of Tashkent in scientific relations between Pakistan and India. In both Pakistan and India there are outstandingly able men who have great plans for their countries. What is more, they seem to be making considerable progress. The range of problems in both countries is formidable, but in both science is receiving growing attention as a major road to solutions.

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