Patel Memorial Lectures

SCIENCE AND SOCIETY

Dr. M. G. K. Menon

PUBLICATIONS DIVISION

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by

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PATEL MEMORIAL LECTURES

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Each year, an eminent person, specialist in a particular branch of knowledge, presents through the lectures the results of his study and experience for the benefit of the general public. The lectures are designed to contribute to the existing knowledge on a given subject and promote awareness of contemporary problems.

The two lectures on the theme "Science and Society", brought together in the present publication for wider audiences, were delivered by Prof. M. G. K. Menon on February 12 and 13, 1973, at India International Centre, New Delhi

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I. INFRASTRUCTURE FOR MODERN CIVILISATION

Jawaharlal Nehru expressed in remarkably clear terms the basic difference between the approach of science and the manner in which society likes to function He said : "What ultimately does science represent ? I suppose, the active principle of science is discovery. And what is the active principle of any social framework of society ? Normally, it is conservatism, of remaining where we are, of not changing, of just carrying on. Thus we come up against a certain inherent conflict between that principle of society which is one of continuity and conservatism and that principle of science which is one of discovery, which brings about change, and challenges that continuity. The result is that the scientific worker, although he is praised and patted on the back, nevertheless is not wholly approved of. He comes and upsets things as they are, and we see that, normally speaking, science seldom has the facilities that it deserves, except when misfortune comes to a country in the shape of war, or the like."

Proper Environment Essential

The growth and development of science and its successful application for human welfare can take place only in an appropriate environment, and thus demand changes in the structure of society so that it increasingly becomes less conservative and more flexible. The social transformation from a rigid traditional structure to newer, more flexible forms, the growth of the scientific culture and its application for producing economic change should in an ideal situation follow almost parallel closely behind one another. In real life social changes are quite difficult to effect.

It is much easier to plant a modern scientific culture in what appears to be for it a wrong environment. This is done because of the strong interaction that exists today between science, technology, production activities and provision of services and the knowledge that modern science and technology make these operations highly profitable and are forces for economic change. The existence of this scientific culture and the economic change that it has led to, one hopes, will enable it to also act as a force for social change. The latter will take place only if there are equally significant efforts at other points such as the transformation Gandhiji tried to introduce in the Indian situation. In the course of these two lectures, I hope to explore this theme in some detail. And in order to ensure that I convey my thoughts to you, not merely as an ideological or philosophical discourse, I intend to place before you a perspective of the manner in which science, technology and society have developed through the ages, and to illustrate these developments with a few pertinent examples and quotations, and then to analyse the situation in which we find ourselves today.

Let us first consider the manner in which science, technology and society are inextricably tied together today in a highly complex manner. To bring this out I would like to give you three examples of developments that have taken place in areas that I know and have worked in and with which I have some familiarity, namely physics.

Discovery and Application

The electron was discovered towards the end of the last century. Within a decade, the first electronic valve, the triode, was invented. In another four decades, immediately after the Second World War, the solid state device, known as the transistor, was invented, giving rise to the birth of solid state electronics, which has today reached a stage when several thousand devices making up an electronic circuit can be incorporated in one tiny chip of silicon. And it is these developments that have made possible modern computers and space programmes, to cite only two examples. Thus within three quarters of a century from the discovery of the electron, the field of electronics has grown in an explosive fashion to permeate human life in a multitude of ways : in the form of radio and television, public address systems, telephones and communication equipment, radars and defence equipment, in computers and controls, in industry and medicine and in a whole variety of ways.

Let us consider, as a second example, the area of nuclear science. It was about six decades ago that the nucleus of the atom was discovered and three decades later that the phenomenon of nuclear fission was observed. Within a few years of the discovery of nuclear fission, atom bombs based on this discovery wiped out the cities of Hiroshima and Nagasaki. Today, there are enough weapons of destruction in the form of nuclear bombs and missiles to wipe out human civilisation totally from the face of the earth if use were to be made of them. But on the positive side, stemming from the same basic discoveries, there is increasing production of electric power through nuclear reactors and the use of radio isotopes in medicine, agriculture, industry and so on. Those working in the areas of nuclear and plasma physics might yet present humanity with a gift of limitless value by taming fusion reactions; these are the reactions which provide the energy in the sun and in the stars, and which has already been seen in destructive form on earth as hydrogen bombs. If the fusion reactions can indeed be controlled, humanity will have an almost limitless amount of energy available to it from water which is so abundant.

In these two fields of electronics and nuclear science, we have seen how the basic discovery of only a few tens of decades ago, essentially in this century, has been developed and found application to an extent where they have an overriding impact on human life.

Let us go on to one more example when the time lag between discovery and application has been much less. Consider the device known as the Laser. Less than two decades ago, was discovered the phenomenon of amplification based on stimulated mission radiation. This made possible the development of masers operating with microwave radiation and lasers operating with light. In the short time that has elapsed, lasers have been used in surgery for attaching retinas in the human eye which have become detached, for large scale destruction in the form of laser guided "smart" bombs used over Vietnam, and for engineering purposes, for alignment over long distances. One is already working on the possibility of using lasers for communication purposes with the enormously large bandwidths that they can provide. We must remember that this field is only a decade and a half old.

These examples illustrate a basic feature that we must recognise. In the world of today the development of science and the corresponding widening of our understanding of our environment and of how nature works is rapidly transformed into technological capabilities which profoundly affect society as a whole.

But this has not been the case through the history of man. To understand this let us look in broad perspective at the manner in which man and society and science and technology have evolved through the ages.

Evolution of Man

The earth on which we live is some 4,500 million years old. Around 3,000 million years ago or so it became possible for self-organising and reproducing species of matter to develop and spread throughout the planet. As remarkable as the origin of life, was the development of forms which, in addition to procreating themselves, could undergo genetic changes to evolve species progressively more able to take advantage of the environment.

It appears that, until about 20 million years ago, our ancestors were ape-like men who spent a great deal of their lives in the branches of trees in forests. About 15 million years ago, there was a transition from the stage of living on trees to that of dwelling on the ground; and this resulted in the development of the upright standing posture, characteristic of man. It took another 10 to 15 million years from the erect ape to Homo Sapiens.

The most significant part of this development was concerned with the evolution of the human brain, which controls most of the abilities that separate us from other animals. Man developed four highly important abilities : namely, tool-making and the general intelligent manipulation of objects; speech and the development of a sophisticated vocabulary; the capacity for social development which permits an increased ability to co-operate within the family or the tribe; and, very important, the ability to reason logically. The last is probably the newest of our attributes and the most crucial one in separating us from the other higher animals.

Growth of Civilisation

Clearly, tool-making, communication by speech and social development all evolved out of the need to live and survive in a hostile environment. The development of logical reasoning probably arose out of competition within our own species or with closely related branches of the manlike family; and it was probably thus that this branch, of which we are representatives, wiped out competing branches such as Neanderthal Man. An important question that we have to answer is whether the instinctive patterns of human behaviour are fundamentally inimical to human co-operation on an indefinitely broad scale.

It is in this process of logical reasoning that science had its roots. And it is our hope that science which has shrunk the world, which has in it the possibilities of untold prosperity for all mankind, and which has demonstrated that there are forms of war such as nuclear wars in which destruction is complete, this science, by the very point it has reached, will unite mankind in co-operation.

The steps in this remarkable process of evolution took place slowly, when judged by the standards of time we are used to in everyday life. From the days when the use of fire was discovered, probably due to Neanderthal Man, who vanished about 50 thousand years ago, through the Old Stone Age based on food gathering and hunting, when man learnt the major ways of handling and shaping materials, and became an exceedingly clever tool-maker contriving complex arrows, axes, spears and hooks, through the New Stone Age (around 5000 B.C.) of primitive village agriculture, weaving and pottery, man entered the Metal Ages of Copper, Bronze and Iron.

The Bronze Age (3000 B.C.) added metals, architecture, the wheel and mechanical devices and the concept of the city; astronomy, medicine and chemistry acquired their first traditions. The Iron Age (1500 B.C.) added glass and improved tools made of a cheap metal—iron. And thus man moved slowly along the path of evolution, adapting himself to the environment and acquiring new traits and skills in the process to survive and develop. Successive landmarks that could be discerned with gaps of millions of years, began to occur with gaps at first of a few thousands and then of a few hundreds of years.

The Birth of Modern Science

Around 1400 A.D., with the Renaissance in Europe, started the spectacular march of modern science, which we are witnessing today. There was clearly an intellectual ferment characterised by the understanding that knowledge was to be advanced not by reliance on ancient authorities but by studying nature and by acting on it. The invention of printing greatly helped the process of recording information and of communication.

We might ask at this stage as to what happened elsewhere in the world. All over, in the early stages of human development, there were pseudo-sciences such as cabbalistic number, lore, alchemy, geomancy and so on. Several of them demanded observations and experimentation and gave rise in time to meaningful science. Thus chemistry is an offspring of alchemy. In all the major civilisations of the world there have been high points and a flowering of intellectual scientific effort, in China, India, Egypt, Mesopotamia, Greece, Islam and the Mediterranean countries. But these have been transitory and have, after passing their creative zenith, relapsed into traditional pedantry.

And then, over a period of about 500 years from around 1400 A.D. to the present century, there occurred two major developments of profound significance. There was the Scientific Revolution during which science attained intellectual maturity and became an indispensable feature of a new industrial civilisation. There was also the Industrial Revolution which was the great transformation in the means of production, based on the use of steam and electric power, steel-making on a large scale and the start of automation.

In the earlier stages of the development of society, changes of technique were in response to economic needs; they could and did take place without any intervention of science, but the advance was relatively slow. At first, it depended on the availability of new materials or methods of handling them such as stone, bronze and iron which led to the Ages of Man named after these, and the introduction of fire, pottery, weaving, the wheel, the ship and several inventions, attributed mostly to the Chinese, such as the stern post rudder, mechnically driven bellows, etc.

Co-ordinating Hand and Brain

Even the Industrial Revolution was almost entirely the creation of self-taught men, wholly independent of the universities of the country—and this was essentially because the universities were functioning on the basis of classical traditions with religious and philosophical, usually endless and fruitless, discussions; they did not have the men who could achieve co-ordination between hand and brain, who had self-confidence and could innovate.

Consider for a moment the situation by the middle of the eighteenth century. Wood was an important material both for fuel and for construction (for example, for ships and houses). The increasing demands for wood were leading to severe shortages, but alternatives were few. Coal might be used for fuel, but its mining was not easy. The easily stripped surface deposits were rapidly exhausted, and deeper mines soon ran into problems. Water had to be pumped from considerable depths, and the coal had to be raised to the surface. Even then the coal could not be used in simple ways for fires by which iron was converted to steel, because impurities in the coal led to contamination and highly undesirable properties in the resulting steel. Wood was thus preferred as a fuel, but it was in short supply. A major part of the solution to this circle of dilemmas lay in the invention and development of the steam engine by Savory, Newcomen, and Watt. In addition, the way to eliminate the sulphur content of of coal by the coking process was discovered, and through use of coke, better steels could be produced. These, in turn, could be used to build better machines.

An interest in such topics led a group of men to meet regularly on the Monday of each month nearest to the time of a full moon. The Lunar Society of Birmingham consisted of only fourteen members. Although some of the members had met earlier, the active years of the society date from 1755 to near the end of that century. James Watt and Josiah Wedgwood were members; Benjamin Franklin was personally acquainted with seven of the members. The society undertook and encouraged scientific experimenting and industrial improvements; its influence was great, far beyond its small membership.

Some Landmarks

Although better steel could permit the construction of vastly improved machines, the design of better steam engines required a scientific understanding of the thermal properties of steam, namely the energy available when steam is allowed to expand, the efficiency of an engine and how it could be improved. The science of heat was developing, but was still inadequate. It was the work of Carnot published in 1824 that laid the foundations of thermodynamics which was fundamental for further developments.

By this time, science was already entering into the technical field in an essential way. In 1843, James Joule showed an unvarying and exact proportionality between mechanical and heat energy. Somewhat earlier, in the seventeenth century, there was the discovery of the vacuum which was so abhorred by the philosophers; this was important for developments relating to the steam engine.

On the philosophical side, the work by Galileo in the 17th century had established the science of mechanics based on experiments with falling bodies and projectiles. Newton reflected on the circular path taken by the moon round the earth and established the form of law of gravitation to the earth-moon distance. In spectacular fashion he made a sweeping generalisation concerning the applicability of the law of gravitation throughout the universe. These and the Copernican Revolution on the sun-centred rather than earth-centred nature of the solar system, the work of Darwin on evolution and of Pasteur in the biological field have had profound philosophical, religious and political consequences.

We have been led to a basic appreciation that there is order in nature which can be seen and studied and there are natural laws which can be derived theoretically and put down in explicit form, the consequences of which can be experimentally evaluated; and further theories and laws can be derived from experimental observations. I have read that when the early Jesuit missionaries went to China and said that everything in nature obeys laws, they were asked as to how this was possible. Laws, after all, have to be laid down, imposed and penalties levied for contravention; how can this happen in the case of the inanimate objects one encounters in nature? It is this type of consideration that has throughout been at the root of the conflict between religious dogmas and science. We must remember that Copernicus, Galileo, Darwin and Huxley were all opposed by the Establishment of those times.

Origins of the Royal Society

At this point, it is also interesting to recall the origins of the Royal Society of London, which was founded in 1660 and is the oldest scientific society or organised scientific academy of any kind in the world which has enjoyed continued existence. In 1645, when the Civil War was raging in England and there was some interruption of studies in both of the then existing universities - at Oxford and Cambridge - a small body of men in revolt from the authority of the ancients decided to meet in London to study the new experimental philosophy. That was the time when the work of Galileo which founded mechanics, of Gilbert in electricity, and of Kepler who first enunciated the laws that govern the planetary motions found no place in the teaching at those universities. These great and fundamental achievements, and the new point of view that they represented, namely that systematic observations and experiments were the proper means of investigating natural phenomena, had their admirers, and these were the men who founded the Royal Society.

One of the founders was John Wilkins, a well-read Churchman, who published a small book in support of the Copernican theory, then already a hundred years old; his book was titled "Discourse concerning a new planet, tending to prove that it is probable our earth is one of the planets." It is interesting that it was the task of Robert Hooke who formulated the basic relationship between stress and strain to furnish the Royal Society every time they met with "three or four considerable experiments."

Fundamental Changes

In these origins of modern science one sees a substitution of blind acceptance of authority by a belief in experimentation and empiricism; a substitution of fatalism by optimism; a substitution of love of tradition by love of innovation. In the context of our situation today, it is important for us to remember that it is these conceptual and profound changes that gave rise to scientific development; and constitute the basis of what we witness today as the spectacular triumphs in the atomic, electronics, chemical, space and modern medical areas.

With regard to the Industrial Revolution, I do not want to give the impression that it was just a simple gift of inventors. We must remember that there were ingenious men in earlier periods of human history in different parts of the world. But it was a combination of circumstances that led to the Industrial Revolution; this includes in an important way economic factors. such as the availability of capital, of labour and the opportunities the market offered for profit. The Industrial Revolution was also paid for by society in grim human figures before enough capital and momentum were generated. What is important is that with the Scientific and Industrial Revolutions that took place in Europe over a fairly contemporaneous period there started the symbiotic relationship between science, technology and industry which has been growing increasingly closer with the passage of time; this has led to economic and social changes of profound magnitude.

I am sorry to say that very few who study science ever consider its history or the manner in which it influenced society and was itself influenced by the conditions that prevailed. Equally, the study of history for the most part is concerned with kings and dynasties, with incidents and events and their time relationships that are largely unimportant; attention is also paid to the religious, philosophical, cultural and, more recently, to economic factors. But history in general, and certainly in India, never goes into questions like how man and society acquired the capabilities which made them function the way they did; there is seldom an enquiry into the complex relationships between social systems and these capabilities; and it would be difficult for historians to carry out such studies without a background of science. The unfortunate concept of the two cultures talked of by C. P. Snow is a reality in the universities of our country.

For us, in India, and indeed in the developing nations of the world as a whole, it is important to learn from the past for clues to the future. We need to understand the conditions, the environment and the climate when changes of a positive nature occurred in the past as also conditions which were inimical to positive development; such an understanding is essential if we plan to move in a positive direction over the future.

Characteristics of Science Today

What are the characteristics of science as we see it today? Firstly, one notices that the scale of scientific advance has increased almost out of all recognition. There has been not just a mere change in magnitude, in the number of scientists or of funds, but a profound change in the scope and sophistication of science, in its complexity, and in the increase in the powers of investigation. The advancement of science and technology is one of the great distinguishing features of our times; and it is in these fields that human creative power today finds one of its chief means of expression

The second important characteristic of current scientific development is the rapidity with which the scientific discoveries are being applied for practical ends. We have already seen how, from early times, techniques developed in answer to the needs of society and were largely accidental or empirical in their discovery and application. The great scientific advances of the seventeenth, eighteenth and nineteenth centuries in the practical understanding of the world around, and the formulation of the laws which nature obeys, have enabled science to increasingly make possible techniques which have resulted in the building up of a world of its own, of mechanical, chemical and electronic devices, the use of which is tending to replace the fruits of purely technical development. As a result, there is an ever-growing dependence of technology, industry and government on science; equally scientific advance today greatly depends on industrial and technological capabilities.

Thirdly, we can trace the transition from the era of "small science" and of "private science" at the beginning of this century to the era of "big science" based on industrial and governmental support. Scientific ventures are to a great extent so large and all-embracing that support for these has essentially to be public and governmental, both national and international.

Lastly, and most unfortunately, we see the extent to which science is being made use of in the armament race. This has been a particular feature of scientific development during and since the Second World War.

Science and War

During the Second World War, we saw the development of radars and of atomic weapons of frightening power, to name only two major entities; and science was also applied for the co-ordination and direction of military operations themselves. During the past quarter of a century, subvention to science by governments for the preparation of new and evermore scientific wars has continued to be multiplied by large factors. The true effects of this concentration and militarisation of science on the eventual growth of science have as yet to be evaluated. It is quite clear, however, that it is resulting in very serious distortions of aims and methods.

Interest of scientists and inventors in machines of war, and in fact consulting for the military, is not something quite new. It has had a long and honourable history; for example Leonardo da Vinci, who is generally known to society for his greatness in the creative arts, was also a great scientist. In his letter to the Duke of Milano, to whom he offered his services, he dwelt extensively on his skills in the art of invention of apparatus of war; indeed it is only at the end of his letter that he mentioned the skills he possessed as an architect, sculptor and painter which might be of use in times of peace. Leonardo recognised that there could be circumstances that might make it necessary to become involved in military work. He said : "When besieged by ambitious tyrants, I find a means of offence and defence in order to preserve the chief gift of nature, which is liberty." But equally he was also aware that inventions could be used in ways neither originally conceived nor to the liking of their originator. In commenting on his ideas for a submarine, he said: "Now by an appliance many are able to remain for some time under water. How and why ?

I do not describe my method of remaining under water for a long time.........and this I do not publish or divulge, on account of the evil nature of men, who would practice assassinations at the bottom of the seas by breaking the ships in their lowest parts and sinking them together with the crews who are in them." He was thus opposed to the indiscriminate development of weapons of horror to be used purely for conquest and exploitation.

Adapting to Rapid Changes

I have so far tried to convey in this talk the manner in which technical knowhow developed in close relationship to the development of society to meet its needs; and how, on the other hand, through human history science and society developed along lines largely independent of one another. The growth of science and of technology and society in the past was steady and slow. There was always an increase in the rate of change, but it was imperceptible on the time scale characteristic of human life. Major changes took place over millions of years at first, then over thousands of years and then hundreds of years; we are now on an exponential growth curve with time scales of growth of the order of decades.

The material mode is not the only one by which science has affected society. The ideas of science have had a profound influence on all other forms of human thought and action: philosophical, political, religious and social. These influences have been more complex than on the economic plane and consequently more difficult to quantify. The ideas of science are not the simple products of the logic of experimental methods or theoretical formulation. They are in the first place ideas derived from the social and intellectual background of the environment, past and present, and then transfomed, very often only partially, by passing through the test of scientific experiment and theory. A full understanding of the ever-changing relations between sciecne and society must take into account not only the material but also the ideological and social factors.

Today, science, technology and society are inextricably tied together in a highly complex manner. We have only a dim qualitative feeling concerning the nature of this many-body interaction. The understanding of this is clearly important for any meaningful and wise direction to be given to human development over the future. From our study of the past, there appear to be clues which we might take note of.

The fabric of our civilisation has changed enormously in our own lifetime and is changing more and more rapidly from year to year and will continue to do so. Society has clearly to adapt itself to these drastic changes in the environment, in the way of life, in the thought processes, and in the scale of values that have been brought about through scientific developments. Society will have to be truly secular, and I mean by this, one which is capable of changing with time, to adapt itself rapidly to the pace demanded by the rate at which scientific development can now take place.

I hope in the next lecture to cover aspects such as the social responsibilities of scientists in the situation we face today, the concept of a world development of science, the structure of society and the concept of modernity that it must contain, as also the essential features necessary for the growth of indigenous science, on an appropriate scale and in organic way, in parts of the world where it does not exist at present; in dealing with the last point I shall discuss the role of language in the teaching of science, the question of relevance in the choice of scientific work, and need to break down class distinctions.

II. A CURSE OR A BLESSING?

I described in yesterday's lecture how science, technology and society have developed through the ages. In the affluent nations of the world, the development now is so rapid that society is finding it difficult to keep pace with it. On the other hand, in the under-developed parts of the world, the development of science and technology on an indigenous basis, that is needed for growth, is not taking place primarily because of the absence of the right environment in the society around and the shortage of capital. This is the dilemma that we face today.

It is clear that the affluent nations of the world have got to where they are through the development of science and technology. I mean this in the broadest terms; in the development of a society and of an environment which permitted the growth of science; in the use of the scientific method to explore and benefit from natural resources; in the development of ingenuity and inventiveness to maximise the utilisation of the human creative elements for progress.

Homi Bhabha said :

> "What the developed countries have and the under-developed lack is modern science, and an economy based on modern technology. The problem of developing the under-developed 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 so, 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 under-developed to a developed country."

Let us now consider, what the problems are of establishing science as a live and vital force in society. I would say that there are three elements which we need to consider on high priority. The first relates to the role of language in the growth of science; the second to the academic relevance of our educational institutions as also the relevance of our scientific effort in relation to the problems immediately confronting us; and the third element relates to the tradition-bound character and class structure of society. I would like to deal with each of these in turn.

Reorienting Education

Before doing so, let me tell you very briefly what I consider to be the essential element of science in its broadest possible connotation. We all have the great fortune of associating with children; and we immediately notice the insatiable desire on their part to know and to understand the world, to find connections between things and events, very often asking questions that are inconvenient and questions that are difficult to answer. It is sad to think that we were also once children with this unbounded curiosity. In contrast, as we grow up to be adults we have a set pattern; we already know the things that are relevant for our ordinary living and are quite willing to work in a circumscribed world, with definite relationships between things, with well established cause and effect, wherein we do not have to ask any new questions but can operate comfortably with what we know and our past experience. We represent society, static and stratified, and the children with their questing energy represent science in a fundamental way. In addition to the element of curiousity and imagination, science has, no doubt, been equipped with all the powerful tools of logic and mathematics, of technology and experience.

As I see it, the aim of education is to fit a child or a young individual for the society in which it will grow up and ultimately work and live in. It is a sobering thought that, with the expectancy of life as of today, and the manner in which it has been growing, the school children of today will be living an important part of their life in the twenty-first century. If we expect our country to develop rapidly and to make progress, science will have to play a significant part; and change will be a distinctive character of society. We should ask ourselves how society will change over this period and how our educational pattern should be oriented to fulfil its primary task. We need basically a new look at the very objectives of education.

Role of Language

Let us now examine the role of language in the growth of science. The growth of science and technology in this country has so far been based entirely on the use of English as a medium of instruction and of communication. The so-called elite of this country, including all of us who have had the great privilege of receiving education at higher levels, represents an extremely thin crust of the human society that constitutes the country. It was no doubt necessary to start at some point, and there must be centres for nucleation and for generating leadership.

The question we have to ask ourselves today is how one proceeds beyond this point in growing a large national scientific community and in developing the scientific temper of the nation. Clearly we cannot continue to operate within a small stratum of society; we have to involve the massive parts of our population who are at present left out of the picture, but who can contribute so much. We have to make them our partners in our efforts. We must recognise that man-for-man there are equal talents available, and that the untapped reservoirs of human potential are enormously larger than the thin crust we represent.

We have to accept the fact that English is not the language of the large masses of the country. And before a language can be used fluently, in which one can think and communicate effectively, it has to be taught properly and be acquired in an environment where it is used correctly. This does not exist, and it is unlikely to come about, in the case of the large masses in this country. At most, they may acquire a smattering of English poorly taught and badly learnt. If science is then propagated through the medium of English, the only chance an individual has of acquitting himself satisfactorily is to memorise. He does not have enough knowledge of the language to have properly understood what has been taught to him nor to express himself. He will depend entirely on what has been taught in form, in content and in language, with no deviations. And this is completely contrary to the whole spirit of science, which is of free independent thinking and expression.

We have to ensure that science does not become just a body of knowledge handed over to a student to be memorised and retained, to be brought out at appropriate occasions, such as examinations. Science can grow only on the basis of understanding and not on the basis of memorising. And understanding cannot come about through a medium which itself is not understood.

Science has to be taught in a natural way, involving a study of nature in all its facets, through a process of making observations and of comparing these with those made by others;

of trying to understand a complex body of observations on the basis of some underlying simplicity, which enables one to build a theory or make a hypothesis; to make predictions based on such a theory; and to make further observations, perhaps on the basis of experiments, to see whether the predictions are fulfilled. And all this can only be done through a medium with which one has familiarity, which normally is the mother-tongue.

Let me emphasise that I am here talking of science which needs to be propagated through the mass of society. The much smaller numbers who go on to become professional scientists engaged in research and become a part of the world scientific community can always learn English at an appropriate stage; and indeed with the numbers involved being small there should be no difficulty in their being taught and learning English or another appropriate major language well.

But for full, positive use of science something more than a passive acquaintance with science is needed. It has to become part of general education with active participation by the large mass of society. This will lead to the rational approach in society and every phase of the productive process in industry and agriculture and of other practical aspects of daily life can become a field of intelligent experimentation, for practical improvement and innovation.

A Practical Approach

I am fully aware of the many difficulties involved in implementing such a programme. In this connection I shall only suggest three definite aspects to be borne in mind, which should go a long way to removing some of these hurdles. First, it should be recognised that we in this country have adopted a democratic way of life; we respect and allow for the varied viewpoints and desires of various individuals and sections of our people, so long as they do not infringe the laws of the land. In a matter of this nature the viewpoints and desires of any one section should not be thrust on the others. Thus, as it stands, each individual should have the choice of opting for an education and language medium which would benefit him or her most. Secondly, words with wholly technical connotations are alien to an individual until they arise during the course of his education and experience. There is no need to translate them for purely parochial reasons of prestige connected with the maintenance of the purity of a language. It is a language which is willing to borrow and grow which has the greatest chance of development. In the case of language as a vehicle for science and technology it is the structure, the verbs, the adjectives, adverbs and so on, and their arrangement with which the students should have intrinsic familiarity.

I am sure that an appreciation of these aspects will enable science to grow on a large social base.

The second factor that I have stated is that of academic relevance, namely that the academic or educational system should have a truly meaning involvement in society. I shall illustrate this with the history of the "Land Grant Colleges" of the United States.

A little over a century ago, in Boston, in New England, a society of artisans presented a petition to the State saying that "we cultivators of the soil, artisans and mechanics wish to see an educational system developed, which will give us and to our children the same privileges which traditionally have been reserved for our professional brethren." Their aim was to set up a system of education different from the classical tradition which was characteristic of the ancient universities of Oxford and Cambridge in England; they did not want universities which would train lawyers and clergy but instead they wanted to produce men who could create wealth. It was in the middle of the American

Civil War, three months after the Battle of Gettysburg, in one of the darkest hours in the history of the United States that Abraham Lincoln signed the bill establishing in each State universities of a completely new type, endowed with grants of land by the Federal Government and thereby called "Land Grant Colleges." Their important role was to study any or all of the problems of contemporary society. This role led them to study problems relating to crops and agriculture, geological survey, water supply; and an extraordinarily fruitful collaboration developed between teaching and industry, in which the scientific method was successfully applied to the problems of industry.

These were the problems that were of concern to the citizens of the country and the educational system, characterised by the Land Grant Colleges, was coupled in a meaningful way to these problems. We would do well to learn from this highly successful example.

Discovery of Problems

This is not an isolated example. And I would like to illustrate this with examples of other types.

Many of the great scientists over the years were men of great practicality who used their time for both discovery and invention of gadgets. These men displayed an interest in what was around them and devised practical solutions for problems to which their attention had been directed.

Galileo, one of the creators of the Scientific Revolution, was the first to clearly understand the role of controlled experiments. Modern dynamics involving concepts such as inertia and velocity originated in his work. His other interest lay in the area of astronomy where his contributions were monumental. He established experimentally our present model of the solar system due to Copernicus in which the sun is at the centre and the planets go around it. In order to do this, Galileo made his own telescope, the first to be used for astronomical devices. Galileo improved upon the design and construction of a variety of instruments. He went into business and made and sold a geometrical and military compass that he had considerably improved. Another great scientist, this time in the field of biology, whose contributions arose from his immediate vicinity and the challenges was Pasteur. Almost all Pasteur's work—the fermentation of beet sugar, and the destruction of silk worms, and the anthrax disease of sheep and cure of rabies—concerned quite practical problems; yet it led to the formulation of new biological principles and the destruction of false ones which revolutionised the conceptual structure of biology.

I mention these examples only to show that men of the calibre of Galileo and Pasteur, who were responsible for revolutionary conceptual developments of science, discovered for themselves the problems that they needed to solve, which often lay in their immediate vicinity. It is important to remember that the discovery of problems is in fact more important than the discovery of solutions; solutions can always be arrived at through the methods of science; by logical argument and careful experimentation. Discovery of problems and an exact formulation of these demand motivation stimulated by the experience of difficulty.

Challenges of the Surroundings

The history of man has always been characterised by his attempts to explore new frontiers, in reaching out to new environments and in understanding and gaining mastery over nature in new ways. We must remember, however, that each individual human being has his own frontier. defined by his intellect and capabilities, and by the extent to which he is motivated to reach out to unknown areas. Most human beings never stretch themselves to these limits. The ultimate frontiers of human knowledge are those which engage the attention of the finest brains with the greatest motivation. The frontier is not something which is set as a defined line of demarcation in a given direction. The discovery of a frontier is indeed the most important element in reaching out beyond it.

Challenges to excite the keenest minds exist in our vicinity and in our surroundings. To meet these challenges one would have to devise new techniques, new instruments and new approaches, which could as easily open a window into the hitherto unknown areas of nature, and lead to work at the frontiers of science and contribute to the world pool of knowledge. It is extremely important for the developing nations of the world to understand that all problems at the frontiers of science are not necessarily those dictated by fashions set elsewhere in the world.

There are no doubt areas of pure mathematics or sub-nuclear high energy physics, or cosmology, where the work in science will be the same all over the world. Men of genius have to be given the opportunity to grow and function as their interests dictate; and if their interests lie in these areas, they must certainly be allowed to work in them, provided the allocation of resources needed for such work is within the capability of society considering the other demands on it.

I would like to conclude this point by simply stating that genuine scientific work at any level must be dictated by deep motivation. It is not something which one does purely professionally to earn a living, nor something which is purely motivated by attempts to imitate and follow current fashions and trends set elswhere. It must arise from the sense of challenge felt by oneself, and where is one most likely to find such challenges? I would say to a large extent they would be in one's surroundings; it is true that the surrounding may sometimes be purely intellectual in its character and be the same anywhere in the world. This indeed is the problem of academic and scientific relevance.

The third and vital aspect relating to the establishing of science as a live and vital force in society is society itself: the problem of making it truly secular and classless. Before I go on to this point, I would like to touch on two international aspects of science.

Science and World Development

The objectives of nations and of governments have for a long time been as simple as they are obvious: to survive, and if possible to conquer, in the competitive struggle with other nations; to face up to poverty of resources and to natural disasters; to keep itself on the path of progress in obtaining better material standards of living for its people. Science and technology have been used as a tool to attain these objectives.

In a sociological sense, one has only moved forward from the earlier concepts of the tribe to the concept of nations. I am here not referring to the internal structure of nations whether they correspond to slave societies or feudal, capitalistic, democratic or socialist societies; I am explicitly referring to the ties that bind people together, of family and clan, of colour and race. Society has not developed to the point where these concepts have enlarged to embrace the totality of mankind in a brotherhood.

Because of this situation, science policy today operates essentially on the national plane, with the objective of increasing and mobilising the scientific and technological potential of a people or a State in the service of the ends which its government pursues. When several governments share the same objective, it sometime happens that they make common use of major resources.

The totality of national interests in matters of science, as in everything else, unfortunately does not coincide with the interest of humanity. Thus, research for military ends receives a very large part of the financing, as also projects whose incentive is industrial competition, domination and finally exploitation; and then come those areas which enhance national prestige.

The intellectual in science regrets this distorted thinking, though he accepts it as inevitable in today's circumstances that governments and industrial enterprises will be less interested in the kind of research whose results will benefit the whole world, than in research from which they hope to derive profit, power and prestige in the competition which faces them.

It is, however, to be hoped when one considers the increased speed at which learning and techniques are spreading, that the whole of humanity will experience development based on science with a world science policy, whose object will be to select the most important orientations of research for the fulfilment of mankind's aspirations, and to derive therefrom the main policy for the appropriation of the scientific resources of the world.

A World Plan

This may seem like Utopia to many. But already, amongst those in the world scientific community who think deeply about the problems of future, there is a growing debate on the respective importance for mankind of the conquest of space, the curing of cancer, control of population growth, solutions of the problems of starvation, urbanisation, forecasting and control of natural disasters, and so on. In terms of action, however, we are hardly entering the stage where such decisions will lead to important political or financial decisions.

But the United Nations and the different institutions connected with it are attempting to make good, and within the political pressures that operate in such world organisations, the difference between purely national science policies (which incidentally are largely non-existent in many parts of the developing world) and a world science policy They are directing their essential efforts towards the concrete contribution which science can make to the economic, social and cultural development of all nations. The funds available for needs of this kind are desperately meagre. Today we have to accept these as the realities of the world situation. However, the United Nations and institutions which belong to it are attempting to work out a world plan for the application of science and technology to development which perhaps may contain the germ of the future science policy at world level.

What has been formulated and published is not the aspect which one should debate about. It is the underlying idea that is important. In order to be somewhat more realistic and recognising the enormous heterogeneity that exists in various parts of the world in terms of the environment, stages of economic development, local problems etc., further attempts have been made to evolve regional plans such as those for Asia, Latin America and Africa, based on the philosophy of the world plan. These are tasks that are at present engaging the attention of the UN Secretary General's Commitee on the Application of Science and Technology to Development.

In these efforts, as already mentioned, the funds available are extremely poor and national pulls very strong. In spite of this, as time goes, humanity will have to realise that it is living on a fragile spacecraft orbiting the sun. The smallness of numbers that constituted human society, the great distances and impenetrable barriers which separated the various elements, the untapped virgin resources of the earth and small material demands per capita are things of the past. The advance of science and technology have increased the numbers, shrunk the world and enhanced individual aspirations; and in this march forward, we have continously been wiping out the concepts of highly structured slave and feudal societies. In the long run. therefore, the advance of science and technology has built in it the imperative need for a world community and brotherhood of man. The question to be asked is the price one pays until one gets there

We would do well to ponder over the significance of what a 16th-17th century English poet had to say :

> "No man is an I land, intire of itself; every man is a peece of the continente, a part of the maine; if a Cold bee washed away by the Sea, Europe is the Lesse, as well as if a promotorie were, as well as if a mannor of thy friends or of thine own were; any man's death diminishes me because I am involved in Mankinde; And, therefore, never send to know for whom the bell tolls; it tolls for thee."

The Social Conscience of Science

With the advent of an upward spiralling nuclear armaments race, many scientists all over the world began to realise that they should concern themselves with the fate of mankind in the atomic age. As a result of this realisation, several national groups such as the Atomic Scientists Association (ASA) in Great Britain and the Federation of American Scientists (FAS) in the USA began to play an active role in trying to establish an important and effective channel of communication between scientists of different nations, particularly between scientists from the great power blocs of the East and the West.

In a speech to the House of Lords in London, as far back as 28 November, 1945, a few months after the Hiroshima bomb, Lord Bertrand Russell had not only forecast the tremendous destructive power of the H-bomb, and the resulting threat to civilisation, but also suggested discussions between scientists of the Eastern and the Western blocs to achieve co-operation and international control in the field of nuclear energy and weapons. In 1954, when the nuclear menace became as great as he had predicted, Lord Russell drafted a manifesto which was signed by Albert Einstein two days before his death; the other signatories of this remarkable manifesto were Max Born, Percy Bridgman, Leopold Infeld, Frederic Joliot-Curie, Herman Muller, Cecil Powell, Linus Pauling, Joseph Rotblat and Hodeki Yukawa. This was one of the most appealing documents addressed to society by scientists conscious of their work, and of the perils of total destruction that had arisen through this. To put it in their own words :

> "In the tragic situation which confronts humanity, we feel that scientists should assemble in conference to appraise the perils that have arisen as a result of the development of weapons of mass destruction......We are speaking on this occasion, not as members of this or that nation, continent, or creed, but as human beings, members of the species Man, whose continued existence is in doubt...... Almost everybody who is politically conscious has strong feelings about one or more of these issues; but we want you, if you can, to set aside such feelings and consider yourselves only as members of a biological species which has had a remarkable history, and whose disappearance none of us can desire......The general public, and even many men in positions of authority, have not realised what would be involved in a war with nuclear bomb......Here, then, is the problem which we present to you, stark and dreadful and inescapable : Shall we put an end to the human race; or shall mankind renounce war ? People will not face this alternative because it is so difficult to abolish war......People scarcely realise in imagination that the danger is to themselves and their children and their grandchildren, and not

only to a dimly apprehended humanity......There lies before us, if we choose, continual progress in happiness, knowledge, and wisdom. Shall we, instead, choose death, because we cannot forget our quarrels ? We appeal, as human beings to human beings : Remember your humanity, and forget the rest."

Pugwash Movement

Early in 1954, the late Prime Minister Jawaharlal Nehru called for the setting up of a committee of scientists to explain to the world the effect a war would have on humanity in the context of the nuclear age. This idea was taken up and went through numerous stages of discussion and development. Finally it was planned to convene a conference of scientists in New Delhi in January 1957; this was the direct outcome of talks between Cecil Powell and Jawaharlal Nehru in 1956. This plan was abandoned, even though invitations had been sent out, because of the Suez crisis of 1956. As a result, the first meeting was held at a small fishing village in Nova Scotia called Pugwash. And thus began these meetings scientists called "Conferences on Science and World Affairs" (COSWA), more familiarly known as Pugwash Conferences.

Whilst the Pugwash Movement had its origins in an attempt by scientists to remove the threat of a nuclear catastrophe, it has, over the years, developed into an international forum to discuss the problems of disarmament in general and problems of development; for scientists see in the growing disparity between the affluent and the developing nations the future threat to world stability.

Individual scientists, well-known and otherwise, have in response to their conscience, come out and taken a stand on questions relating to science and society. But the Pugwash Movement, born out of the awareness that mankind might have to face a nuclear holocaust, was the first international group of scientists to come together in answer to their social conscience, not just to warn society, but to strive for co-operation, for betterment of international understanding and relations, for disarmament, and to ensure that the type of understanding that led to the growth of science might be fostered for other endeavours vital for human survival, for the creation of a secure world in which the beneficial applications of science can be fully developed.

An Integrated Approach

If one examines the periods in human history when great advances have been recorded, one finds that society has been in a state of ferment with a capability for tremendous flexibility. In particular, in the case of science, the great periods of scientific advance occurred when the thinker and the doer, the scholar and the craftsman, came together and interacted with advantage to both; and this could be seen most of all in the Scientific and Industrial Revolutions that occurred in Europe, the history of which I described yesterday.

To a great extent, we find in the past of India that the thinker and the scholar have been closely aligned with the ruling classes whilst the craftsmen and artisans have been at much lower levels, carrying out the tasks that they have been asked to perform. This has been embodied in the caste system which has come down in this country from immemorial past. It was the demolition of this class structure, in the form of castes, and particularly in the form of untouchability, that the greatest of our social workers and fundamental political thinkers, Gandhiji, strove for.

Superficially, this attempt can be regarded from a variety of angles such as those of justice and fairplay, or pity and compassion. But looking more fundamentally and deeply, one can see rooted in this exercise the concept that a static and stagnant society, divided into these rigid caste categories, does not permit the necessary social interactions. In such conditions all human beings cannot move forward, whether on the political, economic or scientific planes. Gandhiji was fully conscious of the need to have an equitable, classless society to release human energies and thoughts along constructive lines.

Let us quickly examine how this operates in our educational system—and we will see a different form of the caste system.

In schools and universities of our country science is today taught with very little attention to practical aspects. This is partly due to lack of finances; for practical work does require space and equipment. On the other hand, I think, far too much is made of this handicap. I personally think it stems from a fundamental characteristic of wanting to be a scholar or a learned person, in the sense of earlier traditional society in which the thinker would not perform anything which would be menial or would dirty his hands; the latter tasks were clearly to be carried out by lower categories or castes. It is now the aspiration of every individual, whatever caste or class he or she may belong to, to aspire, through the process of education, to become a scholar, who will not then have to carry out practical or menial tasks. This mental pattern of older traditional society received a fresh lease of life with the importance given to white-collar work during the colonial regime which was a static period.

It is my view that, for the growth of science, we must make a conscious effort to decrease the value in society of white-collar work and increase the respect and regard in which we hold the artisan and the craftsman, and the man who can actually do a productive, professional and technical job.

Meaningful Education

It is this lopsided value system in society which is creating a mad rush for arificial type of higher education, which does not represent true education for the human being in any sense of the word. It enables the individuals, through the acquisition of pieces of paper such as degrees and diplomas, to be classified as scholars and to obtain white-collar jobs.

I have asked myself often whether it would not be appropriate to completely abolish degrees and examinations and just provide education in a meaningful way for those who wish to obtain it. One can then judge individuals on the basis of tasks that they are able to perform in life which can be judged at the point of entry. This might be considered revolutionary in concept. However, one can ask whether in the evolutionary and democratic process that we have opted for, it is not possible to make radical changes where necessary, particularly in areas that have a profound effect on transforming society such as the educational scene.

How does one expect an indigenous organic growth of science with the present situation in which we turn out an increasingly larger number of individuals, who have gone through a largely theoretical training. and acquired labels which set them apart as a class which is valued more is society than other categories, and when even this theoretical training has been in the form of memorised information obtained through a language the individual has not properly understood ?

It is clear to me that the educational system inherited from our ancient traditions and recent colonial past cannot be the environment for organic scientific growth—radical changes are called for.

Spirit of Rationalism

Throughout man's history, there has always been an attempt to increasingly bring about a rational approach to life and living. There is, of course, a considerable degree of irrationality in all of us as human beings who are moved by impulse and emotion. A lack of understanding of the environment and an inability to control it introduced the basic element of fear and superstition. With the steady growth of science, and improvement in one's understanding of the way nature functioned, many of the fears and superstitions of the earlier periods of man's history have disappeared, though to some extent they perhaps remain part of subconscience. But from time to time new elements of fear, superstition and mysticism build up. Apart from the human being as individual, we have to remember a collection of them as society has many other traditional and structural features which are rigid and archaic belonging to past periods and inappropriate to contemporary conditions.

It is in such a situation that there have been periods of grea' ferment such as those characterised by the French Revolution, by the Russian Revolution and in the emergence of the new People's Republic of China. It is interesting to recall that the spirit of scientific rationalism preceded all of these major events : for example the thoughts of Rousseau, Voltaire and Descarte in France; of the Nihilists in Russia; and for example the student slogan of "Mr. Science and Mr. Democracy" in China in 1919. These are only examples which are not meant to be comprehensive, and are only to demonstrate the desire that existed to overthrow the existing obsolete institutional framework for new very rational approaches.

In India, we also saw the introduction of rationality through religion by Raja Rammohun Roy. But basically, the path to the rational spirit is through science. And undoubtedly, Jawaharlal Nehru was one of the foremost political thinkers of this country in this regard. He has said:

> "I too have worshipped at the shrine of science and counted myself as one of its votaries... I realised that science was not

only a pleasant diversion and abstraction, but was part of the very texture of life, without which our modern world would vanish away. Politics led me to economics and this led me inevitably to science and the scientific approach to all our problems and to life itself... Science, ultimately, is a way of training the minds and of whole life functioning according to the ways and methods of science."

And throughout his life Jawaharlal Nehru strove to inculcate the importance of the scientific temper in the Indian people.

Where Do We Go ?

As we have seen earlier, science grew in the past, steadily and imperceptibly; society at large was unconcerned with its existence. It was only after the Scientific and Industrial Revolutions of a few hundred years ago that one started to see material benefits accruing to humanity through the development of science and its applications through technology. These material benefits could be seen in the miracles of medicine, in the enormously enhanced production of energy, in the improved methods of transport and of communications and in many other ways. There was a general euphoria that there was nothing like the advance of science for human happiness. The general attitude was "let us have more science and then life will be safer, wealthier and more agreeable to all".

But more recently, human society has come to regard the advance of science and technology with a certain element of fear and trepidation. Science indeed has known sin. Mankind has witnessed the destructive powers of nuclear weapons. One attributes to the growth of science and technology a variety of ills that society is beset with : the population explosion; the rapid depletion of natural resources, including energy; the increase in pollution and degradation of the environment; and ecocide.

Suddenly, society is beginning to ask whether the advance of science and technology is indeed desirable and the right way to proceed. Predictions like those of the Club of Rome foresee a highly pessimistic future for the human race on earth. They visualise an incapability for the human race to meet the demands posed by an ever-increasing population with resources available on the earth.

There are many who demand a halt to the growth of science and technology; but they fail to realise that solutions to the problems we face, the problems that I have listed, can only come through further development of science and technology, but a development with a direction which is chosen wisely to enable us to discover the true nature of the problems and then to find the solutions. There is no question of retreating to the past or of halting. Indeed, even if this were to be possible, the world will not stand still but will degenerate, even more rapidly. We, therefore, have to face the future with optimism and ensure that the interactions of society and science are appropriate to ensure the selection of wise value systems and options.

An Explosive Situation

Scientists, of course, have themselves been caught unawares by the manner in which these developments have taken place. Bertrand Russell once said: "Equations do not explode;" and most scientists in their ivory towers have been confidently working on this assumption, that what they are involved in is purely a process of objective and logical reasoning which has very little to do with human society and its real problems. But the manner in which science has grown and is continuing to grow, the rapidity with which scientific discoveries are being applied to practical ends in the present symbiosis of science and technology, and the rapidity in the application of science to armaments, have all resulted in an explosive situation.

The American philosopher, Herbert Marcuse, has written recently : "When the most abstract achievements of mathematics and physics satisfy so adequately the needs of IBM and the Atomic Energy Commission, it is time to ask whether such applicability is not inherent in the concepts of science itself." This being the case the scientific community has to consider not only what is generated as fundamental knowledge, but the entire cycle which leads to application, its impact on society and the long range consequences for the human race. Science cannot occupy such commanding heights of power in relation to society and not concern itself with all that stems or follows from its actions.

One cannot, of course, say that this concept is highly original. Sir Francis Bacon had written much earlier : "Human knowledge and human power are co-extensive." And with the growth of science and increase in human knowledge, there has been a corresponding enormous growth of human power that we have to learn to live with. And it was always recognised, particularly by Bacon, that the advancement of knowledge could be used to support both good and evil purposes. After speaking of the benefits flowing from the advancement of science, Bacon says:

> "Yet out of that same fountain come instruments of lust and also instruments of death. For not to speak of the arts of procurers, the most exquisite poisons, as well as guns and such-like instruments of destruction, are also the fruits of mechanical invention, and well we know how far in cruelty they exceed the Minotaur himself."

Problems of the Future

We have to realise that we are only at the beginning of the period in which science is the determining factor in economic and social life, and we are still hampered by the traditions which grew in a period when science had a very little place in life and where it was treated as an optional factor. What we have to ponder over is what lies ahead in the future, with an increasing growth of science and technology, and the transformation of society from a traditional to a flexible one.

In order to consider this question of the future, we have to ask ourselves where human happiness lies and what the values—material as well as intellectual—are that we cherish and would like to develop. Let us consider some examples of material value that may appear to be mundane, but are indeed of great significance. It is estimated that, in the United States, there are currently some ten tons of steel in use for every member of the population. To reach such a figure in India with its population of 560 millions would amount to a total of 5,600 million tons of steel. This is a fantastic amount of steel. We must ask ourselves: what do we need so much steel for ? Are all the end uses really necessary ? Can we reduce this amount significantly and yet reach a level of material comfort that is necessary for happiness ?

Let us consider another case, that of automobiles. In the USA, the automobile, as a personal form of transportation, has an essential place in the value system and economics of society; and today automobiles contribute there in a significant way to atomspheric pollution. Even if a clean-air automobile was to be produced, it will add to the pressure to have many more of these; the result will then be not only increasing traffic problems but also an increase in the demand for steel and power and we must remember that the production of steel and power do contribute to environmental rundown and one should not attempt to increase the demand for these if alternate pathways exist.

In a society like India, the number who can own automobiles will be limited; and a value system which gives high priority to automobiles will only enhance the differences between classes. A possibility that should be examined seriously, therefore, is the reduction of individual transportation using automobiles and the setting up of an efficient public transportation system. Thus, before a value system and an economic pattern is built up in India, following the U.S. pattern, in which ground transportation is greatly based on automobiles for personal use, one must examine the alternative of an efficient pollution-free public transportation system; it is not that personal transportation by automobiles is to be ruled out, but that it will have limited applicability where it has particular virtue. The optimum solution to problems of cheap mass transportation will have to come from science and technology. And if solutions to this are found, it might have an effect on the over-urbanisation towards which the trends are already clear; for human beings come to urban centres because of the primary instinct to interact strongly. It should be possible to arrange for this without over-concentration.

Individual and Society

This setting up of a value system for society is not something which is in the hands of science. It is a matter in which those concerned with politics, economics and the social sciences have a great role to play; in both trying to arrive at the appropriate values and in educating society at large to accept them. It is not a matter for an order from the elite to the masses but one that can only be evolved in an interactive process. The role of scientists in this was expressed by Cecil Powell, with whom I worked closely, when he said in the first Homi Bhabha Memorial Lecture in Bombay:

> "They are in a unique position to appreciate early the problems, the dangers and the advantages likely to follow from scientific developments and to make their findings known to governments and to peoples.... Of course, the solutions of many of our problems depend upon great

political issues in which most scientists have no particular competence; but nevertheless, we ought to help with their resolution and never to tire in bringing before the people of the world the immense possibilities for human advancement which are now within our grasp if science is rationally employed in a peaceful world."

Science represents knowledge as acquired through an unceasing, critical process of experiment, theory and evolution and the research for such knowledge. In fact, it provides an approach and method for this research. Knowledge and the power that stems from it can be used both for good and evil. It is for all of us to ensure that it will be used as a means towards the goal of human happiness. I am confident of the powers of science and technology to achieve the goal set by society but there has to be an enormous cleansing process to avoid the distortions that have crept into scientific developments and equal transformation of society to enable the right type of science to develop and grow. The last thought I would like to leave with you in this lecture is the fact that whilst the individual human being is extremely important, it is society as a whole which is even more important. The development of science and technology is making this increasingly so and in the happiness of human society will be the true happiness of the individual human being.

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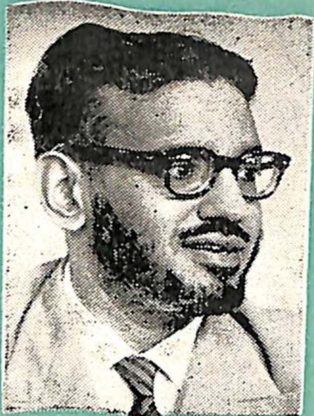

Born in the year 1928, Dr. Mambillikalathil Govinda Kumar Menon is one of the distinguished scholars of science in India. He had his early education at Jaswant College, Jodhpur, from where he graduated in science from the University of Agra. Later, he took post-graduate degree in science from the Royal Institute of Science, Bombay, and Doctorate of Philosophy from the University of Bristol. He was also awarded D.Sc. (h.c.) by the University of Jodhpur.

Prof. Menon joined the Tata Institute of Fundamental Research, Bombay, in 1955 and worked in many capacities till he became its Director in 1966. He is also the Chairman of the Electronics Commission and Secretary to the Government of India, Department of Electronics, since 1971.

Prof. Menon is the Vice-President of the Indian Academy of Science (1971-73); Fellow of the Indian National Science Academy; Fellow of the Royal Society; Honorary Foreign Member of the American Academy of Arts and Sciences; and Chairman of the Cosmic Ray Commission of the International Union of Pure and Applied Physics (1972-75).

Prof. Menon is associated with several scientific institutions, organisations and universities of India and other countries including United Nations' Secretary-General's Advisory Committee on Application of Science and Technology to Development.

In 1961, Prof. Menon was awarded Padma Shri. He was also awarded Padma Bhushan in 1968. Earlier, he was a recipient of the Senior Award of the Royal Commission for the Exhibition of 1851 (1953-55) and the Shanti Swarup Bhatnagar Award for Physical Sciences (1960).

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