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THE ROLE OF SCIENTIFIC OUTLOOK IN THE
DEVELOPMENT OF SCIENCE AND SOCIETY

By

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...The scientific approach and temper are or should be, a way of life, a process of thinking, a method of acting and associating with our fellowmen...

— Jawaharlal Nehru
(*Discovery of India*)

It is with great pleasure and some trepidation that I stand before you today. Pleasure : because I am deeply conscious of the honour at being asked to deliver this important lecture and because it gives me an opportunity to air my cherished views before an enlightened audience. Trepidation : because I am aware of the galaxy of illustrious speakers who preceded me in this Lecture Series. However, I comfort myself with the thought that as a former Jawaharlal Nehru Fellow, I am speaking among friends and not strangers.

It is a characteristic of many great men that their greatness has several facets. If you ask the question 'Why do you think so and so was great?', different people may answer differently. This was the case with Nehru. Some will recall him as a great freedom fighter, some will think of him as an intellectual of high calibre, while others might assess him as a great leader and statesman. The list does not end here. To me, as a student of science, what comes uppermost in the mind is the fortunate circumstance that our country's Prime Minister was a man who not only appreciated science but also possessed a scientific outlook.

Nehru's attachment to science started long before he became the Prime Minister. Writing to his daughter about the quest of man, from the District Gaol in Dehra Dun on June 10th, 1932, Nehru had this to say :

....Science gives a doubting and hesitating reply, for it is of the nature of science not to dogmatize, but to experiment and reason and rely on the mind of man. I need hardly tell you that my preferences are all for science and the methods of science...

Thoughts like these were to prove important for the growth of the new born nation in 1947. They continue to be important to us today. Indeed, towards the end of my lecture, even at the risk of being accused of missionary zeal, I wish to emphasize the

necessity of having a scientific outlook in all walks of life of our developing nation.

What is a scientific outlook? Again, this question may not, will not, invoke a unique answer, even from scientists. I will therefore begin by outlining what I mean by this phrase. I will then illustrate my point of view by giving examples from the history of astronomy and of science in general. Finally, I will proceed to discuss its importance in our everyday life.

THE SCIENTIFIC APPROACH

School children learning science are told that a scientific investigation consists of three steps : the experiment (E), the observations (O) and the deduction (D). This particular pattern of investigation has emerged after centuries of practice of science; and the scientific outlook that I want to talk about lies somewhere at the bottom of it. Science itself arose out of man's curiosity about Nature. Its origin lies in the questions "What?", "How?" and "Why?" that man put to himself and tried to answer. Each answer gave rise to many more questions. While a correct answer closed one particular subject, it at the same time opened up several new ones. And this proliferation of questions and answers has led to the vast and expanding field of science that we see today. Alexander, before he became 'Great', once complained that because of his father's conquests he would be left with no more worlds to conquer. I do not think that man as a scientist will ever be in that position in his battles to unravel the mysteries of Nature.

Let us see how the E-O-D process operates in science. As mentioned above, its beginning lies in some question about Nature, let us say, about a certain phenomenon seen to occur in our physical world. (The non-occurrence of a phenomenon can also be very significant as I will later illustrate with a famous historical example). The experimental part now comes in. The experiment is set up to observe the phenomenon in several different ways. The experimenter can, in many cases, alter the various operating conditions, or the so-called experimental parameters, to enable him to study the outcome in as many

situations as possible. Another object of such experimentation is to eliminate the human element as far as possible and make the results objective.

The next step of observation is not as straightforward as it may sound. The result of the experiment may be qualitative or quantitative. In the latter case the scientist ends up with a set of figures. Before any deductions can be made it is often necessary to detect a pattern in the observed results, and this is where the so called signal and noise come in. Here 'signal' represents the pattern which one is looking for against a background of a maze of data, called the 'noise'. The analogy of a specific sound signal against a noisy background is quite clear. How does one extract the signal? The human eye of an experienced experimenter is very often able to detect this. There are cases, however, of the proverbial needle in the haystack type, where this is not possible and help must be sought from the statistical methods of data analysis. Recourse to statistical methods is in any case desirable to ensure objectivity. Unfortunately, there are situations where even statistical methods are not able to give unambiguous answers. The scientist is then back to the drawing board designing new and better experiments.

The last, but by no means the least, step in this process is that of deductions, i.e., drawing conclusions from the experiment. The scientist is of course, not satisfied with drawing the conclusion for the one experiment he has just performed. He is interested in making predictions for other situations not covered by his experiment, e.g. for situations beyond the range of his present experimental parameters. The purpose of this exercise is to prompt future scientific experiments to be designed to test these predictions. His own experiment may also have been done to test the prediction of a previous scientific theory.

This interplay between theory and observations is what keeps science going. Without scientific theories to guide him, the experimenter will not know exactly what to observe. It is only when the theoretical scientist tells his experimental counterpart some of his predictions that the latter can design suitable ways of testing them. Nor can the theoretician work in isolation forever. Unless he produces scientific predictions which can

be experimentally tested, his theories will be considered sterile.

This history of science is littered with sterile theories and theories which were ultimately proved to be wrong. It is necessary to make a distinction between the two types. The former types, without any observable predictions, did not contribute to the growth of science. The latter type may have been considered viable for a while. These prompted experiments which eventually led to their disproof. But, in this process, the scientist was also able to advance his knowledge. Indeed, the modern scientist knows that no scientific theory, however right it may seem to be at present, will be entirely correct. Sooner or later some new experiment will be designed which will disprove some crucial prediction of the theory. For a while this may lead to an apparent break-down of law and order in the regime of science; but experience has shown that a new enriched order eventually emerges. Thus the disproof of a well established scientific theory is regarded as a very exciting event by the scientist. It means that Nature has considered man to have matured enough to appreciate yet one more of her bag of secrets! It was in this connection that Sir Hermann Bondi, the well-known astronomer, remarked :

...The essential thing in science is for the scientist to think up a theory. There is no way of mechanising this process; there is no way of breaking it down into a science factory. It always requires human imagination, and indeed in science we pay the highest respect to creativity, to originality. It is, of course, clear that since every theory must live dangerously, the casualty rate is pretty high. So we do not honour scientists for being right; It is never given to anybody to be always right. We honour scientists for being original, for being stimulating, for having started a whole line of work. Science is the most human of endeavours because it depends on co-operation, it depends on people testing each other's work and it depends on people taking notice of each other.

— from 'Cosmology Now' Ed.L John
(1973, B.B.C. publications)

It is against this background that one must see what is meant by the scientific outlook. The theoretical scientist tells us that the assumptions on which we propose to attack any problem, must be clearly stated and with clearly defined conclusions. The experimentalist tells us that before fully accepting any such assumptions or premises we must subject them to a critical analysis with as few subjective elements as possible. In short, the clarity of statements with a critical assessment of their validity is what forms the essence of scientific outlook. Although it arose out of the development of science it has proved useful to the conduct of human affairs in a wider context. Nor is the scientific outlook necessarily confined to those who practise science. Indeed, far from it. An illiterate, uneducated human being may be endowed with it whereas a professional scientist may be devoid of it! We will now look at some examples of how this outlook influenced the growth of science.

THE MOTION OF PLANETS

For time immemorial man must have looked at the clear night sky and wondered what the heavenly objects were supposed to be. He must have compared and contrasted their appearance with that of the Sun during the day. From where does the Sun appear in the East and where does it go in the West? Why do most bodies move round a northerly direction, the direction of the Pole Star, whereas a few exceptional ones seem to move in irregular ways? Why is the Moon, which apparently is of comparable size to the Sun, considerably less bright than the Sun. These questions must have occurred to the curious among the mankind in the past.

Now, there is a tendency in the human mind to ascribe strange natural phenomena to supernatural causes. This tendency runs counter to the scientific approach which is born out of curiosity and thrives on a critical assessment. We see an excellent example of the two tendencies in man's approach to the motion of heavenly bodies. The questions raised above could not be answered straight away and so the former tendency was dominant. It is not surprising therefore, that man ascribed supernatural powers to the

Sun, the Moon and the stars. Of these those with the irregular motions were singled out as having greater power because their irregularity implied that they could move across the sky 'at will'. These are none other than the planets of our Solar System. Human imagination being what it is, it was but another step from this to argue that these 'powerful planets' control human destiny. We could understand and sympathise with this view, shared by most primitive cultures, because in those days, more than two thousand years ago, the answers to the above questions were not in sight. But today, when the scientific approach has provided the answers, the situation should be entirely different.

How the scientific outlook prevailed and led to the solution of the mystery is an interesting story which I will briefly narrate. Among the primitive cultures records were kept of the positions of some important heavenly bodies. The reason for these records was primarily utilitarian. For, man had learned to connect the changing of seasons with the changing positions of these objects in the sky. Since agriculture was strongly dependent on seasons, it was necessary to forecast these, and this is where the primitive astronomical observations helped.

Looking at these records, a curious few of the mankind began to wonder whether there was any rule or pattern which controlled the motion of stars and planets. The pattern in the case of stars was discerned without much difficulty, but the planets posed more difficulties. How could one predict the positions of the planets on the sky with reasonable accuracy?

This hard problem was solved, according to the present records available, by the Greek astronomers in the Greek civilization which flourished before Christ. Their efforts culminated in the epochmaking works of Hipparchus and Ptolemy. These astronomers gave elaborate geometrical constructions involving circles, called the epicycles, to describe how planets move when observed from the Earth. With this epicyclic theory they were able to predict where each planet would be at a given time with reasonable accuracy.*

To have detected order beneath the chaotic motion of planets

* In this context 10% accuracy would be considered 'reasonable'.

was a feat of high intellectual order. Yet it is characteristic of the scientific approach that the story did not end with Hipparchus and Ptolemy. For several centuries the description of planetary motion as given in Ptolemy's book 'Almagest' was accepted in *toto*. Indeed, it had achieved the status of religious dogma a challenge to which invited trouble. Yet such a challenge did come — in the sixteenth century.

Nicolaus Copernicus, born in 1473 in a remote corner of what is now known as Poland, came up with this challenge. The central hypothesis of Greek astronomy was that the Earth was a fixed object in space around which the heavenly bodies moved. Copernicus argued that the description of planetary motion became simplified if the Sun was taken as the fixed object. He went on to give his own geometrical constructions to demonstrate this.

In this Copernicus did not achieve any significantly better accuracy than Ptolemy, but no one can deny that his picture is considerably less complicated. What is more, by pointing to the Sun as the Centre-piece, he initiated the next important step : the search for the answer to Why? Why do planets move round the Sun? Thanks to the investigations of Kepler, Galileo and Newton, the answer to this question finally emerged. It was Isaac Newton's law of gravitation which accounts for this motion. The planets are attracted to the Sun according to this precise mathematical law. Their motion is governed by this law of force. On the basis of this law the modern astronomer can predict planetary positions with extremely high accuracy.

We can now contrast the scientific outlook with the superstitious approach to natural phenomena. The view that planets exert influence on human destiny still persists, although the original basis for it is gone. The scientific outlook has led us to the accurate description of planetary motion. Not only that, thanks to space technology man is now on the way to landing scientific instruments on these planets. It should be remembered that the remarkable accuracy of the Viking landing on the planet Mars would not have been possible without a confident application of the laws of science tested through the process of E-O-D.

ARE SCIENTIFIC LAWS SUBJECT TO REVISION?

Let me now turn to another aspect of the scientific outlook as it is applied in science. Are the laws of science, as discovered by the above E-O-D method, sacrosanct and unchangeable?

In principle, the answer to this question is "No". A scientific theory or law is acceptable only so long as it fulfils the criterion that it explains — or at least does not conflict with — any phenomenon observed in Nature. Once it fails to satisfy this criterion, it must either be modified or totally rejected.

It is characteristic of human nature that even the scientists (who are after all human beings!) sometimes fail to appreciate this fact. If a law has been well established for long, but encounters a conflict with a series of experiments, the scientist will resort to a revision of the law only when everything else has failed. This 'everything else' may include new experiments, a different interpretation of the same law, and sometimes a very far-fetched set of assumptions. In his attempt to preserve the status quo he sometimes turns a blind eye to some new revelation from Nature.

The classic example is the advent of Einstein's special theory of relativity. Towards the end of the last century an experiment on light propagation by Michelson and Morley produced results which simply could not be accounted for in terms of the well-established ideas of Newtonian physics. The experiment attempted to measure the Earth's motion relative to a hypothetical medium called 'the aether'. The medium was believed to serve as a kind of background for the propagation of light. Several attempts to measure this motion resulted in failure. No motion was detected. This could not be put down to a lack of accuracy in the experiments. The experiments were accurate enough for this purpose and yet they registered a 'null' result.

Many famous and experienced theoreticians, including Lorentz, Fitzgerald, Poincare and others, attempted to account for this null result within the existing framework of classical physics inherited from Newton, but they were not successful. It was not until 1905 when Albert Einstein proposed his revolutionary special theory of relativity that this riddle could be

solved. And the solution was not of a patchwork type on the earlier attempts, but it involved a radical departure from the Newtonian ideas of space and time.

Today Einstein's special theory of relativity is an accepted part of science. It forms an essential component of the knowledge of the modern theoretical physicist. Yet, its acceptance by the scientific community was not an overnight affair. Most leading scientists viewed it with suspicion, and it was only gradually that relativity became an established part of modern science.

Special relativity dealt one blow to the complacency of the nineteenth century science. Quantum theory dealt another. The scientists of the last century, especially after the highly successful electromagnetic theory put forward by Maxwell about a hundred years ago, had been gradually coming to the view that most of basic physics was already known and that only details needed to be worked out. This view came in for several shocks with the discovery of atomic phenomena. While the classical laws of science predicted a continuity in the behaviour of natural phenomena, those on the atomic scale showed a discrete or a 'jumpy' behaviour. Nothing of the classical physics seemed to fit. It was characteristic of Lord Kelvin, himself a pioneering research worker in classical physics, to enrol himself as a research student at the age of 76, at his own University, the University of Glasgow, so that he could re-educate himself on the newly emerging physics! It was not until the first quarter of the present century that some sort of order came in this 'new physics' through the so-called quantum theory.

The special relativity and the quantum theory together represent the triumph of the scientific outlook in the development of science. The triumph is not only over Nature, over some of the riddles of the natural phenomena, but it is also a triumph over the innate conservatism of the scientific community.

This conservatism of the scientist is his tendency to seek shelter in the established ideas. In spite of his declared aim of 'objectivity' in examining and interpreting scientific evidence, he tends to be hostile to any new theory or interpretation. While this is a justified defence against a host of likely cranky ideas, it sometimes results in obstruction or a delay in the acceptance

of a genuinely sound new concept. How is one to make a distinction between a cranky idea and a good one? To some extent the experience of the scientist helps — but not entirely. Even the most distinguished scientists failed to grasp the importance of special relativity when it was first proposed.

In astronomy today this problem is being increasingly felt. Thanks to the rapid growth of technology after World War II, the astronomer has several new tools at his disposal to probe the Universe. Side by side with the visual optical telescope, he now has radio telescopes, X-ray telescopes, gamma ray detectors, cosmic ray experiments and so on and so forth. He is discovering new and weird phenomena in the remote corners of the Universe. Some of these he can interpret by clever extrapolations of his scientific knowledge gained in the terrestrial laboratory. But there are many others which defy explanations. How should one approach these apparently insoluble problems?

Speaking in this connection in the 1970 Vatican Conference, Sir Fred Hoyle, a leading astrophysicist of our time, has remarked :

...I think it is very unlikely that a creature evolving on this planet, the human being, is likely to possess a brain that is fully capable of understanding physics in its totality. I think this is inherently improbable in the first place, but even, if it should be so, it is surely widely improbable that this situation should just have been reached in the year 1970.

— *From 'Study Week on Nuclei of Galaxies', Ed. O'Connell (North Holland)*

There are some who would join issue with Sir Fred and argue that *nothing* discovered so far requires a modification of the existing laws of physics. To me such an attitude seems dangerously close to the point of view of scientists of a century ago, which I mentioned earlier.

My own personal view is that we may already be seeing evidence in astronomy that our laboratory based knowledge

of physics is incomplete and I will illustrate this point of view by hazarding a guess as to where the next break-through may come.

THE LAW OF GRAVITATION

In describing the history of man's efforts to understand the motion of the planets, I had stated that the law of gravitation given by Isaac Newton successfully accounted for this motion. This law is simple in its statement but profound in its implications. I will not go into the mathematical aspects of this law here, but will concentrate on one particular feature of it. This is the strength of gravitational attraction. This strength is characterised by the constant of gravitation, usually denoted by the letter G . The force of attraction between two masses m_1 and m_2 separated by a distance r is then given by the simple formula

$$\frac{G m_1 m_2}{r^2}$$

Thus the bigger the masses the larger is their mutual attraction and the further apart they are the less is this force. In the terrestrial laboratory we deal with relatively small masses and so this force is negligible compared to other forces around, such as electricity and magnetism. Therefore it has not been possible to do many experiments with this law in the terrestrial laboratory. But the situation is quite the opposite in astronomy where we deal with enormously large masses. The mass of the Sun is some two million million million million kilograms. Our Milky Way system is estimated to be a hundred thousand million times as massive as the Sun. There are strong radio galaxies even more massive than our Milky Way. The question is, "Does the law of gravitation operate for such systems in the same way as it does for the Sun and the planets?" The astronomer works on the assumption that it does. But already there are indications that he may be wrong in making this assumption.

A related question is "Does G remain a constant, or does it change with time?" Newtonian gravitation implicitly assumes that G is a constant. A more sophisticated law of gravitation, given by Einstein in 1915, the so-called general theory of relativity,

makes this assumption even more strongly. What do astronomical facts say?

Recent use of accurate atomic clocks has made it possible for astronomers to check whether G is constant or changing with time. In principle, observations of the Earth and the Moon should tell us something about this. For, if G is slowly decreasing with time the Moon will gradually move away from the Earth and go round it more slowly. The present observations indicate that this may be happening although very slowly. If at all, G may be decreasing by a few parts in a thousand million per century; It is too early to be definitive about this conclusion since it has profound implications for the well established theories of Newton and Einstein. Even if it turns out to be correct, its acceptance by a basically conservative scientific community will take some time. However, it is a tribute to the progress of modern science that such accurate measurements are now becoming possible and the scientist is willing to use them to test the validity of well established theories.

THE SCIENTIFIC OUTLOOK IN DAILY LIFE

I have given these examples from the history of science and from modern science to illustrate how the scientific outlook has been responsible for whatever progress science has made to date. I have also given examples to show how even the professional scientist may suffer lapses from this objective outlook and display a hostility or at least a lack of receptivity to new ideas. Nevertheless, the technological progress we see around us today became possible because man used the scientific outlook for expanding the frontiers of knowledge.

However, the scientific outlook need not be the prerogative of the scientist alone. After all, it owes its origin to human curiosity about Nature and as such every one of us, whether a scientist or not, is entitled to it. Indeed, just as in the case of science, progress could be achieved only when the scientific outlook prevailed over the innate conservatism, so in the case of a society of human beings this outlook acts as an anti-dote to the evils of prejudice and superstitions.

Superstitions are born out of ignorance of how Nature functions. Science is dedicated to the unravelling of the mysteries of Nature. As one particular mystery is solved, we should expect the superstitions based on it to disappear. Yet, this does not always happen in practice because of the lack of scientific outlook in the typical human being. I give below one example.

I mentioned earlier how the early human societies ascribed divine powers to planets. This assumption arose from ignorance of what planets are and how they move. Now that astronomy has answered most of the questions raised about planets by the primitive man, we should expect this assumption to be regarded as groundless. Yet this has not happened. Even in the technologically advanced country like the United States this belief persists among sections of educated classes. As recently as a year ago a group of 186 leading scientists in that country were signatories to a circular denouncing the very basis of this belief. I give below an extract from their statement :

...It is simply a mistake to imagine that the forces exerted by stars and planets at the moment of birth can in any way shape our futures. Neither is it true that the position of distant heavenly bodies make certain days or periods more favourable to particular kinds of action, or that the sign under which one was born determines one's compatibility or incompatibility with other people....In these uncertain times many long for the comfort of having guidance in making decisions. They would like to believe in a destiny predetermined by astral forces beyond their control. However, we must all face the world, and we must realize that our futures lie in ourselves, and not in the stars...

— *from The Humanist* (Sept/Oct. 1975)

Suppose a scientist is asked to examine this question : 'Do planets influence human destiny? How will he go about testing the hypothesis that the answer to this question is 'Yes?' He will not be satisfied by the prediction by a single person based on a

single horoscope. First he will require a set of well-defined rules on which such predictions are based. The rules should be unambiguous so that different persons make the same prediction from the same horoscope. Next he will need to be convinced that these rules work in a statistically significant manner to discount the possibility of the prediction being right purely by chance. This will require a systematic study of a large number of cases under different conditions.

Let me give a simple example to illustrate my point of view. Suppose someone claims to predict with reasonable accuracy whether a tossed coin will fall with 'head' up or 'tail' up. Will a single toss decide the truth of his claim? We all know that any one can predict correctly the outcome with fifty percent accuracy. This chance element must somehow be reduced. Suppose we ask him to perform this prediction-test 100 times, and he predicts correctly 50 times. Again we will argue that this is not a significant indicator of his predictive power. But suppose he is accurate 51 times. Do we give him credit? What if he is accurate 70 times? The statistician comes to our rescue here. He has devised tests to decide whether the success achieved in a particular experiment is purely due to chance or due to some other factor (e.g. the ability to predict correctly in the above case or the possibility of the coin being biased).

Likewise, tests have to be made of the above hypothesis about planets. Such tests as have been conducted so far by scientists have shown negative results. But again, it is not always necessary to call upon the professional scientist to perform such tests. The educated common man can himself sift the evidence provided he adopts an objective outlook.

Of the scientific outlook in a layman, I can think of no better example than that of James Watt. Seeing the lid of a kettle of boiling water being tossed out he began to wonder about the cause and so arrived at the power of trapped steam. This was the beginning of the technological revolution in England. The hostile reception accorded to the first steam engine by the general public is well known, and is a reflection of the prejudice and irrational fear born out of ignorance. Yet eventually this mode of transport became widely accepted.

I re-emphasize in the above example the fact that James Watt was not a professional scientist. But he possessed the curiosity and the urge to experiment which go on to make the scientific outlook. A few months ago we had a similar notable example in our own country. Mr. Chandrasekhar Lohumi, a retired headmaster from a remote part of the Naini Tal district in Uttar Pradesh recently received recognition for his work on controlling the weed *Lantana camara* which is known to be highly destructive to crops. The important fact about Mr. Lohumi's achievement was that he had neither a formal scientific education, nor any sophisticated apparatus at his disposal. But, he possessed the most important asset, namely the driving spirit behind a true scientist.

THE SCIENTIFIC OUTLOOK VERSUS TRADITIONS

India is a country with a long history of refined human culture. It has been, and it continues to be, the home of world's great religions. Its multi-language literature is rich in the thoughts of great thinkers. We, the Indians, are proud to inherit this legacy from our past.

Yet, it is up to us to derive the maximum benefit from this legacy. Do we merely stay contented that we had such a glorious past? Or do we heed and follow literally the views of our forefathers regardless of the time and conditions under which they were voiced? Or should we pick up the essence of their wisdom and adapt it to the changing circumstances of today's world? To me it seems that by and large our present society is happily following the first two approaches and scarcely bothers to give a thought to the third one even though it appears logically the most important.

Let us take the case of Hindu religion. Its primary sources, the Vedas and the Upanishads, are said to be without authors. Yet whoever originated them, was (or were) moved by the spirit of rational enquiry which would have done credit to any scientist today. However, this desire to ask questions and seek answers seems to have got lost behind the multitude of meaningless rituals we see around today. Gone is the simple outlook on

life cherished by our ancient forefathers : instead we have a multitude of do's and dont's under the name of religion or tradition. And the underlying hypocrisy is reflected by the fact that if we don't like to follow certain rules we have been clever enough to invent a set of new rules to act as loopholes.

Let me illustrate this by giving an example. Suppose a business executive has to make a business trip on a certain day. One of the rules says that this particular day is inauspicious for a trip. What should he do? He cannot change the day of the trip for business reasons. Yet he is unwilling to break the rule. So he looks for a loophole. On the previous day (which is not inauspicious) he goes out of the house and leaves some token item with a neighbour. He then returns to his house and goes on his trip the next day as planned. His visit to the neighbour is supposed to mark the beginning of his trip. So he has fulfilled his business obligation on the required day without beginning his trip on an inauspicious day. I present this example to you without comment.

Similar examples may be found in other religions. It is characteristic of all great religious thinkers and philosophers that their greatness is motivated by the same spirit of enquiry that drives the great scientist today. What questions to ask may change from time to time or from one person to another but the desire to know is common to all of them. Yet, by the time their wisdom is transmitted to the common man, by a succession of followers and interpreters, the original humility of the great men is forgotten. Instead their place is taken by the so-called demi-gods or miracle workers.

Partly the common man himself is to blame for this state of affairs. In his desire to avoid the hard work needed for success he is forever on the lookout for short-cut methods. The so-called 'miracles' appear to him the ideal way to achieve his end.

Albert Einstein once said "In this materialistic age of ours the serious scientific workers are the only profoundly religious people." The scientist is the last person to assert that he knows "all the answers". He is forever asking questions and searching for solutions. He does not claim to have an efficient method either. He may blunder through, sometimes pass by, the correct

answer. But he will not accept anything on trust — just because someone said so.

Unfortunately, the hard-headed scientist is yet to discover a 'miracle' in his investigations of natural phenomena. After years of work he has arrived at certain 'conservation laws' which are obeyed in Nature. These laws have precise mathematical formulations and accurate experimental verifications; but in the crude language of the layman they imply the dictum 'you cannot get something from nothing'. A scientific investigation of the so-called 'miracles' one hears of at present would be very rewarding, whatever its outcome. If the 'miracles' are proved to be frauds the society will rid itself of an evil. If they are proved to be genuine it would mean a great leap forward in the advancement of science. As a scientist I therefore heartily endorse the call for such an investigation by competent experts.

THE SCIENTIFIC OUTLOOK IN A DEVELOPING NATION

Speaking some ten years before the independence, Nehru had expressed the conviction that :

...Science alone 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...

— from 'Jawaharlal Nehru'
by Frank Moraes (Macmillan)

Indeed, at first sight these problems before us appear to be formidable if not unsurmountable. Yet, we have only to look at the remarkable progress of science over the last few decades to see that a properly channelled scientific approach holds out hope for the future. The achievements of space technology with such highlights as the manned trips to the Moon, the landing on Mars and the SITE programme in our own country, the rapid growth of communications which has dramatically brought the far corners near, the advances in medicine, biology, agriculture...

are they not scientific miracles happening before our own eyes and achieved during less than the span of a generation? Unlike the so called miracles I mentioned earlier, *the miracles of science benefit not one single individual, but a whole class of humanity.* They benefit the poor as well as the rich. The invention of electric power not only runs the gadgets of the rich, it also provides light to the remote villages.

Let me elaborate a little on what I mean by a properly channelled scientific approach. In a major war, there are several different operations involved. There are planners deciding the strategy. There are factories producing the required armaments. There are complex issues involving communications between different nerve centres. And of course, there are soldiers, commandos, to say nothing of intelligence men. All these and many others do their bit to make a successful attack. So is the case with the scientific attack on the various problems facing the country. For this you need pure scientists to do basic research, applied scientists to consider applications of science to human welfare and technologists to translate these concepts into reality. You also need educated people to acquaint the masses with what science has to offer and to create a climate in which the common man becomes interested in and receptive to the new ideas of science.

In this connection I want to emphasize two points. First, the task of popularisation of science is a very important one. How to get the essence of a scientific idea across to the common man, without killing his curiosity with complex formulae and too many numbers? It is a knack which is not possessed by many scientists even though they may be experts in their fields. It is therefore all the more important that those who are fortunate enough to possess this knack, consciously set aside a fraction of their time for bringing science to the layman.

The second important point is that we must not denigrate basic research. It would be a shortsighted point of view to argue that basic research is an expensive luxury which a developing country cannot afford. To elaborate this, I can do no better than reproduce here an extract from the speech made by Dr. Homi Bhabha, the founder of the Tata Institute of Fundamental

Research on the occasion of the inauguration of the new buildings of the Institute by Nehru :

...By fundamental research I mean basic investigations into the behaviour and structure of the physical world without any consideration regarding their utility 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 the greatest importance to the society for two reasons. First of all, and paradoxically, it has 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...

Dr. Bhabha then went on to point out that the history of science has shown that genuine knowledge of the universe is always potentially useful for man not just because someday action may be taken on it, but also because 'every new knowledge necessarily affects the way in which we hold all the rest of our stock'.

The developed nations have recognized these facts and they continue to encourage basic research. For us to ignore basic research at this stage would mean that we will have to keep on importing new ideas from abroad. This would be contrary to our policy of self-reliance. India has plenty of talent for basic research, most of which is untapped. Suitable support for basic research will unearth this talent and bring in its own rewards in the long-term if not immediately. Right now I can think of one analogy to illustrate my point of view. Imagine a country which has vast untapped resources of oil, but which will not search for these for reasons of heavy financial outlay. Such a country will for ever be dependent on oil imported from abroad. And, finally let me emphasize that basic research does not require

heavy financial outlay. We must, however, ensure with adequate safeguards that the research produced is of first class quality.

Nehru had appreciated this fact and his emphasis on scientific research, both basic and applied, bears testimony to this. The national laboratories, the institutes of technology, the atomic energy programme, the Tata Institute of Fundamental Research, and many other institutions including universities grew up rapidly in Nehru's India. It is to these that we must look for the trained scientists and technologists who will guide our country into the increasingly science-dominated future.

But it is not enough to put the responsibility for the momentous task on the Government alone, or on the scientific elite. The responsibility for nation building extends right down to the common man. And, for him to function efficiently, he must be receptive to the new ideas of science which may at times be at variance with his traditional beliefs.

Writing about tradition and its influence, Nehru said :

"The impact of science and the modern world have brought a greater appreciation of facts, a more critical faculty, a weighing of evidence, a refusal to accept tradition merely because it is tradition...

But even today it is strange how we suddenly become overwhelmed by tradition, and the critical faculties of even intelligent men cease to function... Only when we are politically and economically free will the mind function normally and critically..."

— *Discovery of India*

This was written during the British Raj. Today we live in a free India which is feeling its way towards economic prosperity. Yet we are still a long way away from achieving that scientific outlook which is so essential for our future wellbeing.

While making this plea on behalf of science let me utter a word of caution against an indiscriminate use of the inventions of science. The developed countries are beginning to experience some of the ill effects of excessive and indiscriminate use of science

and technology. We should try to avoid such evils like pollution, drug addiction, the break up of the family as a unit, when we seek to solve the existing problems with the help of science. Let us not end up as intellectual barbarians or technological savages, as the developed countries have been sometimes called. It is here, I think that we can draw on our rich cultural heritage — on the wisdom of our forefathers over many centuries. I am optimistic that if we are not blinded by traditions and dazzled by science but keep our eyes open, our country will make a triumphant entry into the year 2001.