THE ALTERED RELATION OF MAN TO THE UNIVERSE

BENJAMIN BAILEY MEMORIAL LECTURES 1985

DELIVERED BY

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FOREWORD

The Benjamin Bailey Memorial Lectures were instituted in 1983 in the C.M.S College, Kottayam to perpetuate the memory of Rev. Benjamin Bailey, one of the early missionaries of the Church Missionary Society in Kottayam. Bailey's labours were not confined to missionary work alone. He was the pioneer of modern education in this part of the world and by establishing a Malayalam Printing Press he paved the way for the cultural renaissance of Kerala. He presided over the destinies of the C.M.S. College for over quarter of a century in its formative years.

In 1985 the Bailey lectures were delivered by Prof. E.C.G. Sudarshan, the outstanding Physicist of world-wide renown, a native of Kottayam and a distinguished alumnus of the C.M.S. College, Kottayam. The two lectures he gave on 'The Altered Relation of Man to the Universe' give us an insight into the revolutionary changes in man's perception of the universe consequent upon the explosion of knowledge in the decades following the Second World war. They also bear eloquent testimony to the vast erudition of the speaker, not only in science but in Philosophy as well.

The George Sudarshan Centre, C.M.S. College, Kottayam has great pleasure in publishing these lectures.

THE ALTERED RELATION OF MAN TO THE UNIVERSE

E. C. G. Sudarshan

TALK 1

President Abraham, Your Lordship, Ladies and Gentlemen,

My association with this College goes back to three decades, when I entered its portals as one of its continuing stream of students.

The two years that I spent here, were amongst the most important years in my life, because, from being a school student I became a scholar. While we had excellent and brilliant teachers here, like Mr. C. I. Raman Nair, I owe my development to three outstanding teachers: Rev. V. M. Thomas' who taught me Logic; Mr. P. A. Eappen, who tried to teach me Mathematics and Dr. George Thomas- who at that time was Mr. George Thomas- who taught me Physics. It was not only the clarity and the brilliance of Dr. Thomas, presentation that impressed me but also the fact that both he and Mr. Eappen told me: 'If you study Physics; you can study Mathematics afterwards. But, if you become a Mathematician, you are shut out of Physics for ever. While this was not strictly true it was very good advice and accordingly, I proceeded from this place to study elsewhere. At that time, in the Intermediate, there was a group called Group I-A (which was really an appendix to Group I!) which had the peculiar combination of subjects: Mathematics, Physics and Logic. But I am very happy to say that not only did I enjoy the Logic that I learnt but I have found it very useful.

At that time, we had a rarely smiling but an extremely capable Librarian. He too contributed to my growth in this College. I do not mention all the teachers who had affected me but I would like to mention these four people, because they are important for me.

While what is being taught in Colleges has increased in quality and quantity, I have the feeling that at the present time, people are being fed too much information and too little chance to assimilate it. My own recollections are that in the two years that I spent in this College, I rarely had to study what I was taught! For, those things that were taught were taught well and there was a very great deal of time left over. As a consequence of this, I was able to read and study a number of things and I wish that the Colleges, in their wisdom would see to it that the same thing continues.

The purpose of education is not only for the many but the few also have their rights ! I am particularly honoured to be the Bailey lecturer, because Bailey understood that knowledge was to be not only assimilated but also to be processed, and communicated and that knowledge as an artifact had to be processed.

We live in an era of explosive growth in Science and Technology. The amount of knowledge in the Sciences, the sizes of the projects in Science and the share of the Gross National Product (GNP) spent on it, the number of agencies of the Government which deal with Science and the number of people who are engaged in the field have all grown exponentially. It has been estimated that more than 90% of all the Scientists that have ever been are all alive today ! Therefore, it should not be surprising.

if I were to tell you, that most of the Science 'today has been built after I was born and much of it after I was at College here. This explosion in knowledge makes it difficult for any person to know more than a tiny fraction of Science and specialization then becomes the order of the day ! Yet there is a danger with that kind of specialization because one would be missing the whole picture, since we are so involved with the parts.

I do remember Rev. Thomas telling me one day: 'You too have the possibility of being a good student but please remember that, in addition to the subjects that you study, there are a whole lot other subjects and you ought to read art and literature'. It is essential for us to be informed about art and to be able to talk about the way people lived and we need to engineer ourselves into this vast area of knowledge. The very fact that an appreciable fraction of the GNP is spent on scientific research—really not scientific research, but mostly Technology, a close cousin of Science !—makes it important that we be responsible to society for its attention to Science. Even more it does mean that whatever money is spent should be spent on worthwhile projects. Therefore, the scientist has to become a technologist, has to become a statesman and has to become an economist. The scientist has to become well-versed in the art of persuading people, in human relations, in diplomacy and so on.

The earliest branch of Science that we can recognize at the present time seems to have been the study of mechanics of point particles and collections of particles. In due course the study of suitably restricted collections of particles were used to describing not only celestial bodies but also gases, liquids and solids. Naturally, Science began to embrace

not only what is considered as Physics but also, Geology, Astronomy and Chemistry. As the years progressed, one took the study of the human body and somewhat later the study of the human mind and human society and the interplay of people and goods, as the subject matter for Science. So much so, that at the present time, it is very difficult to find a particular area which would not be called a Science. While there was cross fertilisation between various fields, there was still the distinction between different sciences and their flavours. It is a remarkable aspect of the recent decades, that these distinctions and boundaries are at last gradually being blurred. The theory of evolution which was principally intended to apply to Zoology and Botany now applies itself to the evolution of stars, to the chemical elements and even to the very fabric of space and time! By and large, we may say that we have one Science with many specializations.

Along with these discoveries are discoveries about Man himself. What are we? Can we comprehend ourselves as objects and so deduce our own basic behaviour patterns? Are our inter-actions with each other subject to laws? If so, what is the role of ethics in human actions? Where does aesthetics come? Is there something called happiness? Or, is it simply an abstraction? If Science is an unbroken domain from the inanimate to the structure called Man, then we should be able to decide which aspects of Man are still outside the realm of Science and how we relate to that particular area? It is a characteristic of this range of evolution that to everything we have drawn a boundary and then said that Science can come this far and anything beyond this is not subject to Science. We have found that we were wrong, that Science overflowed any boundary that could be set. Nevertheless, it is also true,

that at the present time, I am not aware of a science of happiness; a science of nobility or a science of altruism. It is therefore a scientific question to ask whether our awareness and our inner self itself is subject to the notions of evolution. Or, are there new laws? We know that in language, both in grammar and philology, as well as in syntax scientific laws do operate. The question is: Where is it that scientific laws cease? What is the point at which we are no longer bound by law but act spontaneously?

I would like to digress, at this particular point, and discuss the nature of evolution. Everyone has heard about Darwin's theory of evolution and its modification. It says that species evolve and they evolve mindlessly but appear as if they evolve towards a purpose because of the fact that those that do not succeed are finished off, in the sense that the species, as the popular notion goes, evolve by mutations. Those mutations which are not successful are killed off. Actually, the story of evolution is a little more complicated. There is one level of perception — one level of being a Rishi. Before you actually see what is the mechanism of evolution, one has to understand the reproductive invariance of a particular species. What is it that decides why a particular species preserves its properties; that most of the members of the species are of a particular form and a particular structure? Why do they breed true? Why do they make beings which are more or less like themselves? Once we understand this, then we are in a position to ask ourselves the question: how do we change? After all, all study of change must depend itself on an unchanging background, a standard pattern against which change is being measured. Now we know that this is residing in a certain component of the living system called the genes. The genes carry information and what used to be called

as the writing on the wall or fate (or, the writing on the forehead) is now-a-days referred to as being encoded in the gene. This certainly sounds much more scientific. But the point is that the information that is grossly expressed by the living system is, in fact, an expression, an explicit display of information that is contained in a miniscule form in the genes of which the living system is composed. We shall find that this particular property is not only true of the biological world but, in fact, of all of the world. One might say that we have come to the information era, not only because we have far too much information, but because we have understood that information is the fabric of the Universe rather than objects. Objects are only an expression of a certain level of information: the word becoming flesh, the idea incarnating itself in terms of matter. Matter is really nothing but an expression of an idea! Mutation must be understood within the realm of this particular possibility.

Having understood how a particular system functions, we should be able to ask the question: how is this system able to change? What kind of changes are possible? What kind of changes are beneficial? What is the system out of which things are being made? The present view is that biological systems, or physio-chemical systems, are functioning in an unusual fashion. The distinction between living matter and dead matter is that dead matter functions in a rather unusual way! Ofcourse, the functioning of a living object is much more complex than this remarkable suggestion because we really have to ask the question: given this particular system how will it function in an environment? Because no living system worth its name is living in isolation. It is the interplay between one living system and other living systems and other dead

systems, which makes the situation. In other words, unlike in Physics, where much of the study concerns matter in isolation, or in limited aggregates, the biological system functions within the context of a flow. The nature of the system that is to be studied in a biological context is always that of an open system. A system must not be completely 'knowable' for it to be a living system.

All living systems are unpredictable not only because they have inherent variations but also because the environment in which they find themselves is an open system. An open system cannot be completely controlled or categorized. I am not an expert on Biology and whatever I have said is based on hearsay evidence. But I do know something about Physics. We would like to apply the notion of evolution for Physics and it happens in many time scales.

There are a number of situations in which a physical system is not in equilibrium. One special example, the reason why one hears beautiful sounds from telegraph wires pertains not to beautiful messages going along them but because the wind is blowing against the wires! The steady flow of wind makes the strings vibrate and in the vibration music is brought about. The steady flow of air makes the string vibrate and produces turbulence. Tiny turbulent eddies are shaken off from the wire, one after another. This acts as a bow which makes the string move up and down. As a consequence Aeolian tones are produced. This is one example of a mechanism by means of which a steady non-equilibrium background a changing background—of a physical situation—can produce periodicities and cycles within the system. It is like the case when a violin is bowed by an expert violinist, it prod-

uces music. If it is bowed by somebody who is not a violinist, it produces only noise. Nevertheless, in both these cases, there is an external agent, an agent that you can see: an agent who purposefully acts or is constrained to act in a certain fashion. However, when the telegraph wire sings when the wind blows on it, there is no purposive agent acting on it. The uniform flow of air by itself would not make, in the first instance, music but only a hissing sound! But, a sequence of events within the system makes use of the flow to produce an instability. The instability produces the cycling—the cyclic or periodic motion—which is brought about by the equilibrium. This equilibrium is bringing about the structure of the musical sound. I went into this example in such detail, first of all to tell you that it is a very good idea to walk on the Kodimathachira, or places like that, where I used to walk everyday when I first went to School. These days nobody walks because it is very difficult to walk with so many buses and cars around, But if you did walk and do stand in a place where there are telegraph wires in an open space—open spaces are also rare these days—you would hear these Aeolian tones. Everytime you hear this tone, remember that this is the prototype of life itself! Because this equilibrium under suitable conditions will produce instabilities of a new kind. It will self-generate events and motions which you have not anticipated and as a consequence, new processes and new cyclings can take place.

I have a friend and colleague at the University of Texas. He is a Belgian Physicist by the name Ilya Prigogine, who has made a career of studying non-equilibrium systems. Whenever a system contains a strong non-equilibrium process—open systems through which there are

flows—there is always the possibility of something happening. Whenever something can happen, it usually happens!

Physics has other contexts in which these systems occur. Again on approximately the same kind of time scale is the situation of a pot which is heated from below. Everybody knows of course that if you watch a pot it will not boil too fast but interesting things happen if you heat the water from below in a uniform way. Cold water is heavier than hot water. The flame which touches the pot at the bottom heats it and that water gets hot. It expands. It becomes lighter. It is a non-equilibrium situation when there is a lighter fluid below and a heavier fluid above. The question is —like on our roads!—Who should make way for whom? Or, how does the hot water from above come down below? Because, any place where it wants to come down is like any other place. So there is no place for the hot water to come down. The situation continues for a certain time in which there is an inversion of densities. Eventually when this situation becomes intolerable there is a cataclysmic change. A new pattern is set up in which there is a downward flow of the cold water and an upward movement of the hot water. The situation continually develops in which there are binary cells in which water is going around in circles. Now-a-days with transparent glass, Carafes or Pyrex, you can heat and most of these experiments can be seen very easily. If you put in some little dye, something like Kesar which would produce some colour then you can see streamers in this particular situation. Eventually, a situation arises where the heat is so large that the water at the bottom is sufficiently hot that it begins to develop into steam. First, the air bubbles form. They go away and then the steam, until

the sudden cataclysmic change occurs. In this sequence of events, as the external parameters vary, the mechanism by which the things are taking place varies. In this particular kind of mechanism of an instability being generated by uniform heating, in which all places are equally good, where should the symmetry break? Where should the cataclysmic change happen? Well, the answer is that this happens somewhere, sooner or later. The more important fact is that it happens! It is an example of a phase transition. The change in phase does not happen uniformly but happens non-uniformly.

There is a saying which I coined: any fundamental restructuring takes you through a period of murky vision. The following is something I did learn when I was here. When you have water and freeze it, it will eventually become ice. Ice will crystallize and you can look through it. Before ice is formed and after water has become cold enough to form ice, one can see large patches of ice here and there and at this particular time, the water becomes opaque! Water is transparent and not opaque and so is ice. But in between there is a great deal of cofusion. This is called critical opalescence—a capacity which is induced by the critical point of transition between them. This apparently happens also in human psychology. When your perception is changed rather drastically, there is a certain period at which everything looks very very confused. But the more interesting area in which evolution takes place is in the physical universe that we see outside us which is really in continual change. The universe we find outside us is not to be considered as a given external situation but, in fact, it is formed as a consequence of something.

The usual picture of talking about matter around

us, is to say that whoever made this world made it the way it is and we only talk about motion. We talk about the planets in their motion in the night sky and we say that the planets are moving in ellipses—slightly deformed circles—around the Sun, more or less at its centre. But the planets are given things and for all practical purposes, one simply does not make any enquiries about what they are. One can find out their mass and their position by other observations, but you take them for granted. One would like to know why planets are there? Why is the Sun in the particular situation? Who made it? And if so, could you have a Sun which is a thousand times stronger or one thousand times the size of the present Sun? Finally why is it that gold is rare? So are diamonds. But sand is in plenty. Why is it that some elements are available in large amounts and some chemical elements are available in small amounts?

Why are some particular forms of a particular piece of matter in abundance and why are some things rare? Many of these things can be explained on the basis of geology. One would say that the hydrocarbons which were trapped underneath, from forests of long long ago, formed into petroleum which we are able to extract today, that under enormous pressures brought out by geological forces, carbons crystallized into diamonds. But that does not explain why gold is so rare. Is the chemical composition something that is fixed once and for ever? Is it an explainable or an inexplainable feature? When I grew up, I was under the impression that this was not something that is explainable. Because, the laws of Chemistry and to a certain extent the lessons of Chemistry—suspending some minor extensions brought about by radioactivity— state that every element preserved its integrity in

all chemical transactions. They may hide and mask their property by chemical combinations. But something like gold which is relatively noble did not want to combine with anything because it could not find something worth combining with and therefore the amount of gold neither increased nor decreased. This is directly in contradiction to the notions of alchemy which said that from base metals one can make gold. Is it possible to understand the origin of the chemical elements ? The answer is: Yes, it is, if you want to make a model of the Universe in which matter and the Universe is itself under evolution.

At the present time, we have a theory which is called the Big Bang theory of the Universe which says that at the beginning there was a big explosion. In this explosion was created everything that we see: not only matter, not only the radiation or the light that we see but rather the space and time which we consider to be the matrix of all phenomena. The explosion was unlike any other explosion because it was not an explosion from one region of space into another region of space, but it was the explosion which created the region of space itself. If I may give an analogy, it is very much like blowing up a balloon and considering the two-dimensional surface to be the space. All that an ant crawling on it would know is that initially space was very small and suddenly space is expanding. It was a small balloon which became larger and larger. Likewise, we can picture our space itself as expanding from very small to very large values. One can write down equations for this expansion, the same way as one writes down the equations for space-time. Of course, if things are to expand, then they must be limited. Therefore, at the beginning, there was only so much space and so much time. How can space be limited

without somebody putting up fences at the very end ? Well the answer is that one need not always have something which is unbounded. Something unbounded can be infinite and something which is finite can be unbounded. If a straight line has to be infinite, then it must go on and on and it will have no boundaries. If we wanted to stop at some place on a straight line, we must start at one point and end at another. Therefore, there are boundaries in this case. If we do not want a straight line but only a line, we can make it finite but unbounded, by simply joining the two pieces of the line together to form a circular loop. The loop has no beginning and no end but it is finite, because one can traverse the whole loop by going from one point to another point. Mathematically one can define this, but for our purposes, we could say that an ant could leave its friend at some particular point, cover everything and come back and say, 'I have seen it all. There is nothing more to see !' If space is of this particular kind, it must be curved on itself. So space-time must be a curved manifold.

With these notions, one could ask: If the space was brought about in an explosive moment, and is expanding, since then, what can we say about our Universe, apart from the fact that it was small and expanding ? If it was small and then started expanding, then what we see in the world today would have been at a much higher density at an earlier time. In fact, we arrive at this startling conclusion by observing that whatever we see in the world seems to be running away from everything else, with a reasonably large speed which is proportional to their mutual distance. If we now trace backwards, then what we see is that at an earlier time, we should have been nearer each other and the farthest planets are receding at the

largest speeds. If we divide the distance between any two objects by the relative speed of separation between them, within that amount of time, they would have come together. So, there must have been an enormous amount of density at a particular time. That was the time when all things in the Universe were together. Think of the balloon again. If we put a lot of dots on the balloon and blow it up, every point on the surface would recede from every other point. Since the surface is curved, every point can be arranged to have this property of running away from every other point. Therefore, if we go backwards in time (or ran the film backwards), we would see that at a certain time it was all shrunk together. But, because so much matter is compressed at one point, lots of peculiar things happen. Due to the enormous amount of matter, there will be a tremendous amount of jockeying and pressure. So much pressure that ordinary form of matter collapses. It is like a big packed crowd, there being actually no space and still more people coming. In such a case, people will gradually give up their civilized behaviour and they will get together closer and closer, until they will not even be able to maintain their separation from each other and they will all have to stick together. Something like this happens when ordinary form of matter, consisting of atomic nuclei which have their electronic envelopes, is subjected to tremendous pressure. The electrons will be driven into atomic nuclei and the form of matter that we know at the present time would cease to be. There would be no distinction between one atom and another. The atomic nuclei would be so close together that one cannot even distinguish the species to which they belong. When pressure is very very great, there is no problem in motion. This sounds very strange. The crushed nuclei pass through each other

because they no longer have to respect all the old conventions. The more important point I wish to make is that, at this time, all notion of chemicals species disappears. For, all the electrons have been stripped and they have been sent back in to the atomic nuclei and all the nuclei stick together. It is like a number of chocolates which were distinct from one another when held in the hand and after a little while, they all stick together or coalesce. You cannot distinguish one chocolate from another. In the same sense all the atomic nuclei get together.

Now you can run the film forward. You can ask the question: Suppose you had this big blob and the space was expanding. If all the nuclei were trying to breathe free, what would be the configuration? How many of them would go into gold? How many of them would become carbon? How many Helium? This particular mechanism is called nucleo-synthesis—the creation of complex nuclei from basic constituents. It is called nucleo-synthesis, rather than nucleo-genesis, because, the first step of formation is not the only thing that is involved. Afterwards, there are certain radio-active processes —which are corrections and these are generally known— and, at the present time, one could make a difficult but reliable calculation of the abundance of chemical elements, if this was the mechanism. What happens on the earth also takes place in the distant stars. The chemical elements are therefore not an initial condition but the result of a process. We can reproduce the chemical abundances as an evolutionary aspect of the Universe.

Much later in time, of course, is the formation of clouds of gases and from them, the formation of the galaxies, the formation of the stars. The stars start out being

rather amorphous blobs of gas but then they condenes under their own effects and eventually all kinds of exciting things happen. Again we can ask the question: If the whole Universe was formless to start with and the forms were acquired by a process of evolution, what are the sizes of the objects formed? What could be their distances of separation? Could they be very large and very small? Is our Sun a very special star? The answer to the last question is: No. Our Sun is special in the sense that it is near to us—it is near and dear to us—but it is not necessarily typical and it is not possible to have a star very much larger than the Sun. In fact, Prof. S. Chandrasekhar, when he was a very young man, discovered that if this was the mechanism for the formation of a star, a star could not be much heavier or much brighter than the Sun. There cannot be a star even ten times as large as the Sun which has about one and a half times the brilliance of the Sun. So, we have an understanding of the size of a star, from an evolutionary aspect.

So, at the present time, one may say that from the origin of the universe and the chemical elements, all the way to the formation of the celestial bodies, the formation of geological patterns and after a small gap, the formation of the biological species and their evolution, and to a certain extent the evolution of the human societies again after a small gap, we really seem to have more or less a complete understanding of an evolutionary scientific approach to the question of how various things happen.

Philology and grammar take you one further step. How do the symbols of sound or of communications

acquire certain characteristics? How are the languages processed from one form to another? What parts are changeable because of minor cultural changes? What parts are essentially the deep structure of sentences and of relationships, which cannot change? Of course, as we get more into the Social Sciences—sciences connected more with human beings and their action— we become less and less truthful. We become, first of all, less and less scientific, because we are too involved in the thing. Secondly, ideologies begin to play a much more important role in stating things and therefore, the observations become unreliable. We become, in a sense, interested parties, who become the judges and the juries. Therefore, there is a vitiation or a degradation of the scientific method. But we have only ourselves to blame and therefore, we have to do the best that we can. So, in this fashion, one may say that we understand things.

There are also activities about study of transfer of materials and goods and services between people. The science of Economics, though always wrong in its predictions, is usually correct in explaining why it went wrong! The explanations are so good that we suspect that Economics is a science! The important point that I wish to bring to your attention is that, therefore, in physical sciences, biology and social sciences, what we observe, perceive or experience and what is historical, measurable and available now, is an external condition, which is itself a result of evolution. Therefore, the real laws, the real objects, the genuine initial conditions of the scientific enquiry are things which are one step removed from our observables. What we considered as fundamental laws are themselves subject to flux. This is the major change that has taken place in the sciences, in recent times, namely, that

not only in personal growth and in spiritual search, but also in the realm of hard and not-so-hard sciences, the laws and the phenomena involving the fundamental entities are no longer what we started with. One feels a a sense of vertigo. There are, in fact, no hard and fast principles. It appears that anything that we consider to be fundamental seems to be someone else's play ground for making them a derived consequence of something else. Just as the gross body is a consequence of the expression of the genes, which express and propagate themselves, in the same sense, one may say, the basic levels of matter that we find and their organizations and their laws are, in fact, gross expressions of finer laws, which are underneath this level of functioning, which is necessary for us to be able to understand the real function of the thing. Thus, the study of evolutionary things in the sciences is of such a nature that it tells us that science is a very dynamic enterprise

Science is not a closed field. It is very unlikely that there would be any time when science would discover all the laws. All the laws which were thought of at one particular time are now no longer sufficient. One wants to know who has these laws. How did these laws come about? In one of P.G. Woodehouse's books, I had read about a situation in which, a venerable club finds one of its members was not quite respectable. So everyone wanted to know who proposed that man. And, who allowed him to join the club. When the people responsible for his admission were known, several members were very angry with them. When someone more conservative and more tradition-oriented questioned as to who proposed those who proposed the not-so-respectable member, and so on, until everyone was involved. In the same fashion

we ask: how do these things take place? Or, how do these come about? The answer is; 'Oh, it is because of such and such laws.' The attention now shifts. You areno longer interested in verifying this particular point. Because, you know that whenever this law is there, these things operate. How did these laws come about, which become the content of another level of activity? I would like to say that this is a very good thing bacause it makes the subject of Theoretical Physics possible. Otherwise, it is an absurd idea that there is something called Theoretical Physics. Physics is a science of matter, energy and of motion. It deals with experiments or measurements and with the external Universe. How is it possible to have Theoretical Physics? Shouldn't you be in the laboratory? I have always a great difficulty in convincing my friends and relatives that I am a Physicist but that I do not have a laboratory. The point is that the laboratory is, in fact, the set of laws that other people have found. You do not want the raw data because that is processed by somebody else. But like in an assembly line, we deal with a different layer of things. The laws of one layer become the subject matter of another layer of investigation. We hope that in this particular fashion we come across better understanding of the nature of the Universe.

It is not quite clear to me as to how to break this lecture into two parts, because the same title is for both of them. So I am going to arbitrarily end soon. However I would like to mention a few points. One of them is the fact that we have not talked about the notion of explosion and our relation to it. Secondly, I have not said anything about our changing relationship with the external universe, except to say that it is not what

we thought it was. The external universe is more subtle, richer, more dynamic and more interesting. It is said that a thing of beauty is one which is forever new. Anytime we think we have pleased nature, there is yet another component of her which is not pleased. Everytime we think we have discovered all reasonable laws of nature, the whole thing becomes unstuck. We have always new things to discover and nature is immensely beautiful.

This is true not only of the physical Universe, it is true of literature, of philosophy, of dreams and of all kinds of things including the search for the inner man. Entirely parallel, equivalent and related to this external universe is an internal universe. Our relationship with the universe is not always very reasonable. It does not follow the laws that govern the external universe. We do not want a universe which is unlawful or contravening the laws. What are the laws inside the universe? It is usual for most scientists not to talk about anything except the external universe because it is much safer to do so. There are a few who keep deciding what should be the temper of science. They lay the foundation for scientific temper so that everybody else will follow it. They are all people who would like to say that all reality lies in things outside, without realizing that the things outside are also stuff of which I am made and you are made. Some of you may be divine in your make up but most of our body is certainly very material. Our body is subject to the same laws of Physics and Chemistry as any other stuff. Fortunately, we maintain it in such a fashion that the laws of Physics and Chemistry are themselves used to protect it from the same degradation that a piece of matter removed from us would suffer. The working of our nerves and the brain cells are certa-

inly subject to the same laws of Physics and Chemistry as the things of which they are made. So, if you want to talk about the external universe, this is also external, because we can talk about the functioning of the various things and their structure, which are part of matter. Therefore, in fact, there is *really nothing which is not part of the external* universe and I would like to maintain this position but still say, as Sankaracharya said:

Viswam darpanamāna nagaree
tulyam nijāntargatam
pāsyan ātmani māyayā beharivot
bhootam yathā nidraya
yah sakṣāt kurute probotha
samaye swātmanam ewadwayaṁ
tasmai Śri gurumurtaye namaḥ
idam Śri dakṣināimuyrtaye

It is said that when you put curry leaves into curries, particularly into curried butter milk, even if you do not like it and take it away, and you do not chew it, you will still get its flavour. In the same sense, I hope you get the flavour of whatever I enunciated. Roughly it is that what is considered outside is really what is inside: that really there is no distinction between what is outside and what is inside. It appears to be so because you are asleep to this particular awareness. The awareness is brought in you by the true teacher who wakes up the true inside of you to be able to make you realize the same. So, if that is so, if this is a possibility which one must consider, then must find out something about the inside. So, in my next lecture I would like to talk a little bit about the relation to the information content, the adventures of science and see how we relate to the

information which is not considered scientific, namely discoveries about ourselves.

I did not say anything at all about Technology which is considered to be close to science. Science and science-based technology have shown that despite the very large population in this country and in this world, we can produce enough food, enough shelter, enough transportation and enough of the things of the world to be sufficient for everybody, as much as they want plus some more. Of course, we do not have enough to satisfy everybody's greed for material possessions or enough for everyone to exhibit their power and dominion over other people. But we do have enough to eat, to clothe, to shelter to transport, to communicate and to teach each other Unfortunately, we find that in our society these things are not distributed properly. We find many educated people who are jobless and many who do not find anyone to teach them. We find plenty in one part of the world and starvation in another part of the world. We must understand why this social viscosity, this economic viscosity and this information viscosity exists. It is like an artery which has been completely clogged by deposits so that it is no longer able to pump things from one point to another properly and eventually the heart cannot really deal with it. We live in this society and we have to deal with our contemporary society. So this is another question to which we have to address ourselves. Hopefully, I may be able to talk about both these things tomorrow. Technology has produced things and science has helped technology to produce these things. But science and tecnology and we as human beings must ask the question: How is it that if all the required things are produced, we still do not have enough ? No man can live in more than

one room at one time. No one can eat twice as much as he needs for sustenance. No man can havs more shelter, more than twice as much as he needs. No man can be transported to more places than he can possibly want to go. Then, how is it that we are unable to distribute nature's bounty and enjoy it ourselves ? So, I would like to stop at this particular point today and come back to it tomorrow.

Thank you.

THE ALTERED RELATION OF MAN TO THE UNIVERSE

TALK II

After the experiment on the bending of light rays during a solar eclipse, and finding that the theory of relativity predicted by Albert Einstein was confirmed by experiment, some reporters went to see Sir Arthur Eddington and talked to him about it and finally said "Dr. Eddington, I am told that you are one of the three persons who understands the theory of relativity. That it is so very difficult that very few people understand it". Eddington told them that it was not correct, but he still asked "Who was the third ?" So when one has to be absolutely honest, it is very true that there are very few people who do understand, and it is only an individual who can decide whether he has understood a theory or not.

In this second lecture, I would like to tell you a little bit about information, knowledge and the consequences of them and the way in which they are related to each other. How do we deal with information ? What is the mechanism of arriving at the general truth ? What is the purpose of arriving at the general truth ? Are the laws there and we discover them or do we invent the the world? Is the world as we want to see it to be or is the world really out there and we happen to chance upon it ?

There are two ways of arriving at the general truth. One is the path of deductive logic and it is the path of perfection, Like all the paths of perfection it is dead. But

it is exact. The standard methodology of deduction is that of Syllogism. You have a major premise which states the general conclusion and a minor premise which states and restricts the domain of discourse and deduces the truth for the reduced domain and you have the conclusion. The usual example given is a sad one: All men are mortal; Socrates is a man and therefore Socrates is mortal. But this is a method in which there is scope for two different shades of opinion. Either you make the deduction correctly or you are incorrect. And two people proceeding along the same major and minor premises must arrive at the same conclusion. This particular syllogistic piece of reasoning, of course, has no relation to experience. Because the major and minor premises are given but their validity is not discussed. The process of reasoning is therefore a mechanical one. Correspondingly there are methods of dealing with this universe. You are given a particular law, and you as a person subject to this particular law, relate to it and arrive at a particular conclusion. You execute it. In this case there is no question of what is the law and what have you to do with it? There is no merit or demerit. It is a mechanism of a mathematical discussion and the only question is therefore, given a variety of major and minor premises which constitute a complex system, the question of computability. Is it possible to compute all the results of the system? For example, what is the largest prime number? A prime number is an integer which has no factors other than itself and unity. The first few prime numbers are 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31 and so on. Is there a largest prime number? This is not a result which can be obtained by a straight-forward computation. Because however much we try, we can find a larger prime and there is a limit for our computing ability.

One has to recognise that four score and ten years is the time which is usually allotted to most of us and not all of it could be devoted to this problem. If you enumerate the procedure step by step we cannot arrive at the result. It turns out in this particular case that there is no such thing as the largest prime number because one has shown that the number of prime numbers is infinite. The proof goes back to probably Euclid or long before him. This is an example of a decidable proposition.

There are a number of situations in which even given this deductive system there are systems of arithmetical arguments where there are propositions which are neither true nor false, which can neither be proved nor disproved. They are formally undecidable. So even though the method appeared to be dead and of no interest, it is of interest to note that even if all the major and minor premises are known, there are certain arguments which cannot be decided or deduced.

In all these cases there is a certain lack of context. What is the context ? What are we talking about ? What is the major premise ? The abstract syllogistic arguments would say "All S is M and all M is P and therefore all S is P". For all that we know, S could stand for Students, Staff or Simpletons and similarly for M and P. Therefore the truth has no bearing on our life and therefore we simply do not know whether the truth we have deduced has any relation to us. However, there are mechanisms for making this kind of syllogism a little more physical and relevant and this was the mechanism of the earlier and independent formalisation of arguments called the "Indian Syllogism". In Indian Syllogism one has not a three-limbed argument but a five-limbed argument in which you have

a major premise and an illustration of it in terms of experience. We have a minor premise and conclusion but you don't end there and say that this conclusion is eminently reasonable because it has applicability. This five-limbed syllogism is in some sense similar to the notions of metaphor in a contemporary language. When we make use of a metaphor, it is not something which is abstract but a good metaphor has some relation. Most of science is in some sense like the five-limbed syllogism in which the major premise and the conclusion are not both in the abstract but in relation to us. Therefore, what we have to do is not to convert science and academic knowledge into technology and use it for the upliftment of humanity, which is in itself a very worthwhile ambition, but the relevance of science to life is in some sense to relate the scientific statements to be statements of our experience —not to make it relevant in terms of applying it to lower levels of activity but applying it in relation to our own experience. The conclusion should also relate to our experience. So one of the ways in which we have to have an altered relation to the universe is that the knowledge of the universe should affect us and not the univerese. If we affect the universe, then of course it becomes technology, an application of science to our endeavours and enterprises which by themselves are worthwhile things to do but that not the primary purpose of is science. The primary purpose of our science is a changed attitude to the universe because we know it better.

There is of course another valid form of a knowledge gathering system which is called inductive inference. In inductive inference the knowledge is context-based and knowledge is related not only to the facts but also to the level of knowledge. Knowledge is information and

information is something which has to be processed—something like when an ore is mined, eventhough it is valuable, we do not leave it like that but it is something which has to be processed. The knowledge information processing system is therefore a purpose of science. This kind of knowledge by definition is imperfect knowledge. It is incomplete knowledge: it is knowledge which is dynamic because the status of the knowledge is continually changing. The reason in this case is not mathematical and fool-proof but imaginative, innovative and plausible. It therefore becomes necessary to apply the fifth limb of syllogism, namely the verification and authentication of the conclusion by comparing it with our experience. Therefore verifiability, or verification of the truth, is an essential part of the thing. Again in our altered relation to knowledge, you must not simply deduce the conclusions and be content with it. We must ask the question: Are these conclusions which are highly plausible relations true? Can we really experience them or relate to them? Therefore it must enable us to look on science not as a heavy burden that we carry, not as a *normative* hypothesis on us nor as a set of rules but rather as a grand hypothesis, that all we know will be changed if we find a better way of comprehending and systematising our experience. This is a very different picture of science from the traditional idea that science is absolute knowledge, that whatever is scientific has a validity which goes over and beyond whatever is human. In fact, it is quite the other way round. Whatever is human, whatever is our own primary experience is of greater value than the laws and the books. I may say along with other prophets before me that I have come to liberate you. I have not come to reimpose the laws and the prophets on you but to liberate you and

to say that all the laws and all the scientific rules and systems are only guides and suggestions, only hypotheses which are helpful for us to comprehend the universe.

We ourselves in our relation to knowledge, in our systematisation of experience, in our comprehension, in our refinement of knowledge must consider all these hypotheses as tentative and must continue to investigate whatever comes in our way. Science therefore put greater and greater emphasis—not in the manner of asking the question: "Is it really true?"; but—on a better way of comprehending what we know and what we have experienced. It is said in connection with people and their relation to altering themselves, that it is much easier to attempt a behaviour therapy rather than to change one's self. If you want to change your way of looking at the world, it becomes difficult. What we can do is to change the way in which we react to things. We might dislike somebody saying something. We cannot change that particular aspect but we can change our reaction or response to it in a certain fashion. Therefore, very much like in Economics, in Electrical Engineering and various other areas, we must not really insist on always knowing the inside working of things but we should be satisfied with an input/output working mechanism. We should say that being so, this follows; these particular sequences of events have these consequences. One also should recognise that every such hypothesis, every such mechanism that we invent, is used for a certain purpose. We would like to act like a pure politician and would have no permanent alliances. We should therefore consider the possibility of changing our model. Usually what we do, however, like ordinary politicians, is not to discard our alliances completely to say that when there is a conflict

between that alliance, and a greater alliance, there would be a question of precedence as to which precedes which. Therefore, we really have to talk about levels of knowledge and levels of models. If one is to ask the question: "Is a given object a solid?" The answer could be, "Yes, it is". But however if the interrogator asks, "I thought it is said that the object is made of atoms and atoms themselves are really not solids?" The answer is again, "Yes, you are right. In fact it is not a solid but it only appears to be a solid. It consists of atoms which are rather soft entities". The question of whether it is a solid or not means different things at these two different levels. Atoms themselves are convenient abstractions, for certain configurations for which the electromagnetic potentials are functioning in a certain fashion. That becomes more real. At a deeper level, when we ask what are electric fields, they are a part of a grand unified field and until at last everyone of these hypotheses becomes a convenient abstraction and building blocks at one level become analysed at another level. The building blocks need not necessarily be smaller entities but in fact it may turn out that they are larger entities. The important thing is that any level must be such that all functioning at a lower level can be understood or comprehended in terms of approximations of a level. So much so, depending upon at which level we want to describe something, we would have hierarchy of the things of the world. This Is true not only of matter but also of things pertaining to knowledge.

It is well known that in India, which can pride itself on its ancient past, one should search about not only the world outside but also the world inside. What am I? Who am I? The following is a very touching story: On

the eve of the famous battle of Kurukshetra, Karna, who was brought up by a foster father and mother without a knowledge of who his own father and mother were, rose to the position of a General by his skill and loyalty, asks himself: "Who am I ? I have risen as high as a warrior can, to the position of the Kourava army, and I have at last found a chance to meet those people who insulted me in battle and and teach them a lesson. On the other hand, who am I? I still do not know, who my father and mother are. I do not know, who my people are". It is said that when his agony became so great that he could not contain himself, Kunthi, the mother of the Pandavas, appeared before him to tell him, "General, I am your mother. You are the descendant of the noblest of the noble, the Sun god himself". A dialogue between them ensues and at the end of it all, Karna ends up by making a promise which would assure the destruction of his own physical body. It is said that in the battle, because of the constraints that he put on himself, he did not win. He actually got killed. His head fell down but his soul went up.

We have methods of processing information and of an engineering of knowledge. This particular engineering of knowledge variously called as Artificial Intelligence, expert systemsor KIPS-Knowledge Information Processing Systems. It is a new way of looking at what a machine can do. A machine can be made to compute and to perform things according to law. The machine can be taught mechanisms by which the laws can be deduced. In fact, a machine can be asked to prove the theorems in Geometry. In elementary geometry there are many theorems and most of these were due to Euclid, For generations teachers have taught these theorems to the students and made

them learn to prove them. Proving theorems in geometry is non-mechanical. Because the cleverness or otherwise depends upon the person being able to perceive the problems in a certain fashion. You cannot teach to someone who has no knack for it. Such people can be taught a particular proof but not to create proof as they want. Apparently, we can teach a machine how to do this. Theorem proving by a machine is very interesting. To illustrate the kind of theorems which one encounters in geometry, let us consider a triangle with vertex A and with sides AB equal to AC. So AB = AC, therefore angle B is equal to angle C. You are supposed to conclude from the first hypothesis the second one. The usual proof is as follows: Draw a bisector of the angle A which meets the side BC at D. Now we look at the triangles ABD and ACD. By hypothesis AB = AC, AD is common, these two angles are equal and therefore the two triangles are congruent. Therefore the corresponding angles are equal. This proof requires a construction.

One of my friends who was a student of the same Professor with whom I worked, got a job in IBM, after he finished his Ph. D. At IBM he was asked to do something interesting. He was asked to invent a machine which can prove theorems. He tried to prove on the machine the same simple theorem of geometry which we mentioned before. The machine was given all the hypotheses necessary for proving the theorem. The machine looked at the two triangles ABC and ACB which belong to the same figure, without any new construction. Since AB = AC, AC = AB and BC = CB. Therefore the two triangles are congruent. This particular computer is cleverer than an ordinary human being, because practically nobody had seen this proof. (However, in the history of mathamatics, there exists such a proof). The machine

was very clever in coming up with this proof. The machine went beyond the usual deductive proof, to arrive at a simpler and cleverer proof. It was able to see that already there are two triangles, without having to make any additional drawings, from the identity of which we are able to deduce the congruency of the triangles. This is a second level of use for the computer—for proving theorems in geometry. A next level of sophistication is to say: Are these the only kind of geometries that we can talk about, the one invented by Euclid? Could we invent other geometries? Or better still, can the computer deal with systems of arithmetic also? Can it discover mathematical truths? At the present time, there are computer programs for Artificial Intelligence which can deduce new geometries. It has come to the point, that it is much easier to make a computer to do this.

We will now come to another kind of intelligent operation which the computer does. Computers follow instructions given in appropriate user languages, called programming languages. The ordered sequence of instructions called programs, for given problems, in a programming language are written by people who are designated as Computer programmers. The Compiler, which is itself a program, then translates the instructions in the user language into the machine language (which is based on the binary system of numeration).

An expert is one who has discriminating experience in a particular domain sufficiently often and in a detailed fashion; whose knowledge of the system enables him to draw general conclusions from his study. Medical doctors are examples of such experts who diagnose the disease of the patient from the symptoms. Can a

machine do the job of an expert? Expert systems of the present day, as mentioned earlier, are knowledge based systems which do such a job. The knowledge from experts is first obtained through several detailed discussions with them and it is then incorporated into a set of rules. An expert system could perform at an expert level as well as at lower, simpler levels. Our own methods of thinking can be duplicated by an expert system. This field is at present in its infancy and our country, with its recent liberal import policies, is in the right stage to enter and make significant contributions in this area, called Foundation Software Technology.

The Computers which have such expert systems would belong to what is called as the 5th generation. The Ist generation Computers made use of thermionic valves; the 2nd generation made use of transistors; the 3rd generation made use of imprinted chips and the 4th generation Computers are the present generation machines which use Very Large Scale Integrated Circuits. As the computers advanced from one generation to another, in these four generations, computer speeds became greater and greater and their abilities to store became larger and larger. But, the 5th generation of Computers are more human. They deal with non-digital computation; plausible reasoning and arguments which correspond to real life situations. This kind of development of the Computer systems, endowed with artificial intelligence is a real threat to our experts. For the expertise of humans can be mined and stored away in a Computer. This process of learning from experts led to some revelations to the experts themselves who discovered that they were indeed following some rules where none apparently exist! This situation is similar to

that of a native speaker who often does not know how a language is constructed but who can immediately spot the incorrect usage of the language by others. Apriori the native speaker may be unable to come up with the reason for the error in the incorrect usage but a careful analysis would certainly reveal the violation of rule(s) of the language which is responsible for the error.

The triangle problem discussed earlier is an example of how a Computer can reveal newer ways of looking at given problem often analysed before. Much of our problems with our contemporary society is that the traditional ways of looking at society have exhausted themselves. We simply do not know how to deal with sufficiently complex problems. The idealist who can affect society is very easily discouraged because after some time one finds that there is simply no unique way of doing things piece-meal and therefore to solve problems one has to deal with things as a whole.

In our Society at the present time there are lots of divergences between the way in which we want something to happen and the way it really happens. In some sense instead of finding out what is the mechanism by means of which Society is functioning and strengthening it, we have put in arbitrary rules, only to find that the methods of dealing with Society have not been successful. The second thing we notice is. the big difference often encountered between what we say and what we mean. There exists a parallel syntax which indicate what we actually mean when we do say something. This naturally makes life very difficult since practice is entirely different from principles. It is therefore important to recognize the divergences between the intention of the speaker and the spoken word on

the one-hand and between the principles and the practice on the other hand. We must somehow reduce this bifurcation. If we reduce this bifurcation, then we will perhaps see that the principles under which we act may be comparable to what we practice. Learning proceeds by analogy. What is valid in one domain may have a validity which goes beyond that particular domain. For example, in a gas where many molecules are running around, when left to itself results in the Maxwellian distribution of velocities. Which is a very well defined distribution with just one unknown parameter. One would have thought that the equilibrium distribution would correspond to equipartition of energy. The reason why the Maxwellian distribution results is because of many exchanges between the gas molecules—even if all the gas molecules have initially the same velocity, after many collisions some would have lost, thereby resulting in the Maxwellian equilibrium distribution. This is a natural law. One can ask whether this has applications beyond gas molecules, in domains such as sizes of institution, the agglomeration of people, the distribution of goods and services within many cities of the country, and so on. The model for the gas has to be thus explored. One can ask whether any other distribution is possible? A constant energy distribution can be arrived at, provided there is no free interaction between the molecules, but all the molecules pass between two narrow walls so that every time the gas molecule impinged on the wall with too little energy it acquired some but if it impinged with too much energy it lost some of it to the wall. Then it would reach equilibrium, a constant energy distribution. Likewise, within society also one must make use of models to obtain certain results.

Another concept from physical science is that of Poiseuille's law according to which the flow in a tube is inversely proportional to the square of the area. Consequently, in a narrow tube, however much one increases the pressure, the flow cannot be increased. This is due to viscosity. When the viscosity is very high, increase of pressure cannot result in an increase in the flow. In the human body also when the arteries become smaller and smaller due to deposits of fat, (eventually they become very narrow, and blood will not flow) to ensure the normal flow the heart will have to pump much more and after a certain limit the heart strikes work and stops. Similarly, we have a viscosity for the flow of information—for eg. in elections there is no flow of information though there is a great deal of propaganda. From a purely physical situation we do learn about what could happen to society.

Finally, I want to end with the remark that in modern Theoretical Physics one has noted that the basic building blocks need not necessarily be the very small. Mathematicians discovered many years ago that not all surfaces have two sides. A Mobius strip is an example of a one-sided surface. Modern traffic engineering has shown that it is possible to have two roads crossing without traffic being obstructed and with free access from any road to any other road by making a clover-leaf exchange. So, new connectivities can be brought about. These connectivities are not properties which are local to any particular point but are properties of the totalities. Modern Physics is beginning to employ these ideas in the context of construction of physical systems; in which the characteristic properties are stable because they are not local and belongs to the whole. What we need are there-

fore examples of this type with regard to our Society, which is to be improved not by necessarily local changes but in the inter-relationships or connectivity between the people. These inter-relationships require in a sense a higher look at society. The laws of Physics and Mathematics must change as our knowledge increases. With experience knowledge increases and as we process our knowledge better, and better, we find that we must look at the same facts from different points of view. The same must be true of society. The true synthesis of the past and the present is not in amalgamating the two but in the present altering the past so that the uture may be a blend of the past and the present. I hope that despite the rather large number of ideas presented, you'll find something of the excitement of being a theoretical Physicist.

It is a great privilege to be a Physicist because here is one endeavour in which you are of this world and out of it, at the same time!

Thank you.