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SOME THOUGHTS ON TRUTH

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It has been a great honour and privilege for me to serve the Academy as its President for two years. I am thankful to the Fellows of the Academy for their kindness and co-operation. To the officers and members of the Council I am indebted for the time and attention they gave to the work and affairs of the Academy : they have been most kind and co-operative. My sincere thanks are due to the Executive Secretary, Dr. B. K. Nayar, and the Academy's staff for their devoted work carried out often under trying conditions and inadequate facilities. It has been a real pleasure for me to work with them.

It is an especial pleasure and honour for me to welcome our new President, Dr. B. P. Pal. The Academy is privileged to have as its President a person of such great scientific eminence, experience and mature wisdom. Dr. Pal's wit and amiability are unequalled. I wish him every success in his work.

I apologise at the outset for my temerity and naivete in the choice of the subject: *Some Thoughts on Truth.*

Recent developments in physics—I have particularly in mind the complementarity principle, and epistemological basis of quantum mechanics—throw a new light on the notion of *truth* and *reality*, and of scientific explanation. It has an important bearing on the cultural and spiritual crisis man faces today. The new trends have a highly suggestive resemblance to certain aspects of Indian philosophic thought. Erwin Schröedinger's *My View of the World* (Cambridge University Press, 1964) and the introduction by von Weizsacker to Gopi Krishna's *The Biological Basis of Religion and Genius* (1973) immediately come to mind. All these are no sufficient grounds to entitle me to speak on this subject. What I may plead in my favour is that if only truly knowledgeable people spoke and wrote—and none others—it would make communication dull and spell ruin for the publication industry. And more than that, I believe, it would adversely affect advancement of knowledge itself, especially scientific knowledge. We all know that experts by their training and inclination feel uneasy and fearful to ask questions which clash with prevailing fashion and style of their disciplines. (Most people over thirty are experts of one sort or another). Many problems despite their extreme significance and relevance tend to to be ignored because these do not neatly fall into well established disciplines. Sometimes their very existence is doubted and denied by the "established" experts. A novice also has a role.

Science is the search for truth. The practical value of science has been astonishingly great, beyond all expectations. A selfless, unfaltering devotion to truth and the

use of knowledge for man's upliftment are the ideals of a scientist. Truth is what all earnest scientists seek. But what is *truth* ? What is true knowledge? Is there an objective criterion of truth? Are there no real truths except mathematical, and possibly scientific? What about ethical truths? Is not pursuit of science itself a moral commitment, an ethical truth, not derivable from science? Are not scientific truths and ethical truths complementary? We cannot derive from science why some people love science, or why there should be science at all. *Are there any absolute truths or are all truths relative*? Are these meaningful questions or otherwise? Is it possible to define truth precisely, at least in the domain of mathematics? An elucidation of some of these questions, especially the last one, is a major achievement of our century and one of the greatest in the entire history of man.

What is Truth?

What is truth? I take a dictionary, say, *The Little Oxford Dictionary,* and look up the word 'truth'. I find that : "truth=being true; loyalty, accuracy, integrity, etc; that which is true, true statement, 'account', belief, etc; reality, fact". I now look up the words 'loyalty', 'accuracy', and all the rest that are supposed to give the meaning of the word truth. [For example : reality=real existence; and existence=fact and fact=what is true]. A dictionary can only tell me what "truth" is, if I know what "reality" is; and I know what "reality" is, if I know what "existence" is; and I know what is "existence" if I know what is "fact"; and I know what fact is, if I know what "truth" is. We are back at the starting point. A dictionary is of no avail for definition of truth, or as a matter of that of anything.

There are many things which most people know nothing about, but there can be no person, never was, or ever will be, who has no notion of truth. We know *intuitively* the distinction between truth and untruth, at any rate in most cases. But intuitive concepts can lead to logical contradictions. The atomic concept provides an example of profound historial significance. So long as it is an intuitive concept—that is, an atom is pictured as an extremely small ball—the atom can be imagined to be divisible into parts, and those into still smaller parts, and so on till its elements vanish into "nothingness". There is no escape from this logical contradiction. The atomic concept was rejected by the Vedantic and Buddhist thinkers (notably Nagarjuna). The way out of the difficulty has proved to be totally unexpected. It has taken more than two thousand years . The discovery of the quantum of action has shown that the atomic concept is *not intuitive—an atom is not a "small ball"*. An atom is both *indivisible* and *divisible*, and it involves no contradiction because of the *non-intuitive* nature of the concept. The "antinomy of the liar" is another well-known example.

Suppose a person makes a statement : "I do not have courage to speak truth". This is an innocent way of saying "I am a liar". You may be inclined (I do not know) to accept this statement as true (call it *S*). If you do, then you are admitting that the person has courage to speak truth. This means that *S* is false. So if you assume that *S* is *true* the conclusion is that *S* is *false*. And if you assume that *S* is false, then you are admitting that the person has courage to speak truth; and hence *S*, the statement made by him is true. The same statement *S* cannot be *both true and false*. That is an inescapable contradiction.

Take another example. Suppose a person says, "X exists". Its negative is "X does not exist". The two statements are contradictory. Suppose he says "I do not exist". If I accept this to be true, I must conclude that the person exists, otherwise how could he make the statement? To say "I do not exist" is to assert "I exist". To deny one's own existence is only to affirm it. A person cannot experience his *own* mortality. *Consciousness cannot experience its own coming into being (birth) nor its own extinction.* That is totally impossible.

The origin of the logical contradiction in these examples is *self-reference*. If we say that a sentence "S" is true, and if "S" itself contains the word "truth", we are obviously in for a vicious circle, an antinomy. In the second example the paradox arises because the notion of "I" includes necessarily the notion of existence.

Suppose I say "I do not have courage to put my hands into hot water". No contradiction arises if you assume this to be true. This is unlike the case when I say "I do not have courage to speak truth". On the other hand there is an inherent contradiction, because of self-reference, in the following two statements :

The sentence below is true.
The sentence above is not true.

Call the first sentence S_1 and the second S_2. If I assume S_1 *to be true*, I must accept S_2 to be true, which says that S_1 *is false*. If I assume S_1 is false, then S_2 is false; therefore S_1 is true. We cannot get out of the contradiction : S_1 *is both true and false.*

[A well known example is Richard's antinomy, formulated by J. Richard in 1905. Consider the sequence of expressions W_1, W_2,....which define all possible properties of integers. Then for a given integer n, either n has the property represented by W_p, or it does not have the property. We write symbolically $W_p(n)=+1$ for the first case and $W_p(n)=-1$ in the second case. Now the expression $[W_n(n)=-1]$ defines property of integer n, and so it must be represented by some W in the sequence $(W_1, W_2....)$. Suppose it is W_q. Then for every n for which $W_n(n)=-1$, we have by definition of W_q, $W_q(n)=+1$. Put $n=q$ and there arises the contradiction $W_q(q)=-1$ and $W_q(q)=+1$.]

A logical definition of truth is confronted by the antinomy of the liar. A way out of this fundamental difficulty we owe mainly to A. Tarski. (A. Tarski : *Logic, Semantics, Metamathematics,* Oxford (1956) ; *Scient. Am.*, June 1969). The starting point is an analysis of the basic features of *Common or natural* languages. The characteristic of common language is its universality—its *unlimited* competence in giving expression to our ideas. Basic to definition of truth is the concept of a "formalized language", that is, language restricted to a precise specified vacabulary and rules of syntax. We can regard the language of a standard text book of science as an example of "formalized language". The notion of truth can be precisely defined for "formalized languages", but only by explicitly recognizing that no such definition can be constructed for common languages. A consequence of this is that there must exist meaningful statements which though *unprovable* are nevertheless true. *Truth* and *proof* are not equivalent (*even in mathematics*). That is an amazing development, not at all easy to comprehend.

Mathematical Truths

How do we know that the three angles of a triangle add up to *exactly* two right angles ! Physical measurements on actual triangles can only tell us that the statement is true approximately—within the limits of observational errors. We cannot eliminate observational errors altogether. *That is impossible.* If we use a straight ruler to draw a straight line, how do we know that the straight ruler is straight. Compare it with another. But is the comparison ruler straight? Why not use rays of light to form a triangle, its three sides made of three intersecting light rays? But the question still remains. How do we know that light travels in straight lines? If the space itself is "curved", as it probably is on a cosmological scale, then for a triangle on the cosmological scale the sum of its observed angles will not be two right angles. [It appears that the observed angle subtended by a "rigid rod" instead of decreasing linearly with distance, tends to increase for distances exceeding red shifts larger than $\lambda/\lambda_0 \sim 2$].

The simple fact is that no measurement, no experiment or observation whatsoever, is possible without a relevant theoretical framework.

No Theory, No Experiment

An experiment is a test of its underlying theory. An experiment is designed to test some specific theoretical result or prediction; and if the experimental result disagrees with the theory, it is a call to improve the theory. Improvement of theory is a continuing process resulting from a systematic continuing confrontation with experiment. A radical improvement often comes from incorporating new mathematical ideas—the new mathematical ideas may themselves have been encouraged by experimental developments. But often there is a big time lag between discovery of new mathematical ideas and their meaningful incorporation in scientific theories. Mathematical truths as regards their validity or "reality" are completely independent of *experience.*

A mathematical theory or discipline, say Euclid's geometry or analytical dynamics, starts with a small number of *axioms* and *undefined terms.* The truth of the axioms and the meaning of undefined terms is *assumed* to be known intuitively. It is not open to question or investigation within the framework of that theory. The development of the theory consists in proving new theorems on the basis of the axioms, and theorems already proved. There are no prescribed methods of proof nor precisely defined criteria. Proofs are acceptable so long as the arguments used are self-evident, that is, intuitively convincing. The new theorems, unless trivial, are of course first "discovered" and then proved. Discovery is an inspired guess, a flash of insight. It is not a step by step process, but a sort of quantum jump of a well-prepared imagination. A rational account of a discovery, the proof, follows and not precedes the discovery (as every research worker knows).

Gödel and Tarski : Proof and Truth not Equivalent

The notion of proof is as old as mathematics but, what is called *formal proof* is a comparatively recent development. A *formal proof* makes no use of intuitive arguments how so convincing these may appear to be. It uses only a small fixed number

of "rules of proof" (rules of inference), so simple in content as to be self-evident. A *formalized theory* depends only on its prescribed set of undefined terms, axioms, and rules of proof. It is a remarkable achievement of modern mathematics that intuitive arguments which over the last 2500 years have led to great discoveries can be replaced in most cases by *formal proofs.* It is not always necessary to do so. It can be left to a small band of mathematically gifted logicians; the rest can carry on effectively, as they do, making new discoveries, with intuitive arguments.

The development of the new notion of *formal proof* has led to a totally unexpected discovery. It is so profound and novel that its significance, mathematical and philosophical, would take a long time to be generally appreciated. K. Gödel (1931) demonstrated, as is well-known, that any non-trivial formalized mathematical system, e.g., Theory of Numbers, must necessarily be *incomplete.* In other words within the system there must exist mathematical statements which can neither be proved nor disproved. The system must contain *undecidable* statements. We cannot get over this situation by including the undecidable statements in the set of axioms of the system. The modified system will still contain new undecidable statements, different from those of the original system. Undecidable statement, is an inevitable accompaniment, ingredient, of every non-trivial mathematical scheme.

Take the celebrated Fermat's statement. For integers x, y, z, and n, the equation $x^n + y^n = z^n$ has no solution, for n greater than 2. No one yet knows whether this is provable or undecidable. What Gödel's theorem asserts is that the Number Theory necessarily contains *undecidable* propositions. But it is most unlikely that a specific meaningful example could be identified.

We have considered the notion of *formal proof* and the profound consequences following from it. What about the notion of *logical truth,* that is, what is the definition of "true sentences"? This is a very abstract and intricate subject. We have to distinguish, as mentioned earlier, between formalized language (or object-language) and the richer (meta-language) which contains the formalized language. The conclusion reached by Tarski is (*Logic, Semantics, Metamathematics* p. 273] :

"For every formalized language a formally correct and materially adequate definition of true sentence can be constructed in the metalanguage with the help only of general logical expressions, of expression of the language itself, and of terms from the morphology of language—but under the condition that the metalanguage possesses a higher order than the language which is the object of investigation.

If the order of the metalanguage is at most equal to that of the language itself, such a definition cannot be constructed".

The notion of proof can be translated into formalized or object-language. On the other hand, the notion of truth cannot be so reduced. It lies outside the "object-language". It belongs to the "metalanguage" (or common language). All provable statements are true statements. But the converse is not true. Every formalized system worth its name must contain statements which are true but not provable within the framework of the system.

The *a priori* notion of truth helps us to make fruitful choice of axioms and rules of proof for a formalized system. It serves as a valuable and inspiring (but not unfailing) guide for development of mathematics. As Tarski observes : "There is no con-

flict between the notions of truth and proof in the development of mathematics, the two notions are not at war but live in peaceful coexistence" [*Scient. Am.*, June 1969].

It is apparent from the foregoing discussion that a formal, analytical treatment of intuitive concepts can lead to unexpected results. The distinction between *proof* and *truth* is probably the most significant achievement. To mention another striking example, the concept of *area* (on curved surface) and of *volume* comes to mind. About forty years ago. A. Tarski and S. Banach showed that if we discard intuitive (geometrical) ideas of volume, and seek to define the concept in terms of the abstract *measure theory*, the result is unbelievably strange, though mathematically indisputable.

To quote from E. Kasner and J. Newman, *Mathematics and the Imagination*, G. Bell and Sons, London, 1961, p. 207 : "There is a way of *dividing a sphere as large as the sun into separate parts so that no two part will have any point in common, and yet without compressing or distorting any part, the whole sum may at one time be fitted snugly into one's vest pocket.* Furthermore the pea may have its component parts so rearranged that without expansion or distortion, no two parts having any points in common *they will fill the entire universe solidly, no vacant space remaining either in the interior of the pea, or in the "universe".* And they continue : "Surely no fairy tale ... can match this theorem of hard, mathematical logic. Although the theorems of Hausdorff, Banach, and Tarski cannot, at the present time, be put of any practical use ... they stand as a magnificent challenge to imagination and as a tribute to mathematical conception".

To ask the question whether the theorems of Hausdorff, Banach, and Tarski are true, is no different from asking the question whether it is true that the sum of the three angles of a plane triangle equals two right angles? The answer is identical in the two cases. *The theorems are true.* And this irrespective of the fact that the one appears so obvious and the other so incomprehensible. The highly abstrcat HBT theorems express mathematical truths, which, how so counter to common sense these may seem, are nonetheless incontrovertible in the "world of thought". But this is not to imply that there corresponds to these theorems a physical reality, that is, these have a physical application. But if past experience is a guide, deep mathematical ideas sooner or later turn out to be relevant to our understanding of the natural world. (May be, the elucidation of the singularities attending gravitational collapse call for the HBT concepts : We do not know). The question whether a mathematical truth has a physical or scientific relevance is a question not in mathematics but *outside* it. It is a question that belongs ultimately to experience—to *experimental science.* It cannot be decided by intuition and reason only. It requires an appeal to experience, to sensory knowledge. The distinction between mathematical truths and scientific truths is crucial. The basis of one is *reason,* of the other *experience.* The two, of course do not function in isolation from one another. But the two are different reminding us of, and related to, the difference between *mind* and *matter.* Mind can conceive spaces of any number of dimensions (and with different types of matrices), but it is experience of the exterior world which leads us to conceive physical space as three dimensional.

The roots of primitive experience—concepts such as proximity, identity, truth—are possibly embedded in the genes. A new born child has from the very moment

of birth considerable, surprising competency to deal with the world around him, as shown by some recent studies in child development. A child is born as an extremely competent individual. The competency has been acquired through the biological evolutionary process of our species extending over millions of years. We may say in a manner of speaking that every child is born with certain *truths,* the basis of its competencies, engraved within it. These truths are as much an expression of the genes as is the body.

As atoms are prior to genes so also we should regard mathematical truths as prior to evolution. James Jeans in a famous lecture many years ago declared God to be a pure mathematician. Of great interest are the observations of M. Delbrück on the *a priori* aspect of the concept of truth in mathematics with its far-reaching consequences. To quote Delbrück [Nobel Prize Address (1969) : *A Physicist's Renewed Look at Biology, 20 years later*].

> "Thus, even if we learn to speak about consciousness as an emergent property of nerve nets, even if we learn to understand the processes that lead to abstraction, reasoning, and language, still any such development presupposes a notion of truth that is prior to all these efforts and that cannot be conceived as an emergent property of it, an emergent property of a biological evolution. Our conviction of the truth of the sentence, "The number of prime numbers is infinite", must be independent of nerve nets and of evolution, if truth is to be a meaningful world at all".

A machine like a computer "knows" *proof* but not *truth* (as distinct from proof). Its "language" is "object language" and not natural language. It is possible that *the mystery of truth is embedded in the mystery of time itself.*

Theories in Science

We spoke about truth in logic and mathematics. In natural science, as described earlier, a theory or explanation is always tentative, waiting to be replaced by an improved, more comprehensive theory. The only way a successful theory can contribute to further advancement of knowledge is to suggest new problems and experiments which provide new tests for the theory. Failure of a theory is frustrating and painful for its authors; but it is failure, and not success, which leads to improvement of existing theories. All this is now common scientific philosophy, thanks to the epochal contribution of Karl Popper. His famous formula ($P_1 \rightarrow TT \rightarrow EE \rightarrow P_2$) expresses the quintessence of the method of science. Here P_1 stands for problems which serve to test the theory; the testing of the theory is symbolized by TT. The testing leads to elimination of errors (EE) in the theory. The improved theory suggests new problems P_2 ; and the process repeats itself. *A Scientific theory is always provisional.* It is guide to further development, to its own replacement.

It is apparent that there is, nothing like a "true theory". That represents an *ideal* a limit that can never be attained. The road to a "true theory" is an unending one. It is an endless quest. The notion of "ture theory" serves as a motivation for continuing improvement. It functions as a true ideal, inspiring but unattainable.

SYADVADA LOGIC

At this point I should like to say a few words about the logic of *Syadvada,* also called *anekantavada* or *astinasti* vada. (*Syad* means "may be"]. This was formulated by Jain thinkers more than two thusand years ago. It is the logic of complementarity par excellence. It should be of great interest, both scientific and ethical, in the modern context. Its relevance to statistical concepts has been discussed by P. C. Mahalanobis and J. B. S. Haldane (*Sankhya,* May 1957).

According to the *Syadvada* scheme every fact of reality must be described in *seven* ways. These are combinations of affirmation and negation :

(1) Existence, (2) Non-existence, (3) Occurrence (successive) of Existence and Non-existence, (4) Inexpressibility or Indeterminateness, (5) Inexpressibility as qualified by Existence, (6) Inexpressibility as qualified by Non-existence, and (6) Inexpressibility as qualified by both Existence and Non-existence.

Syadvada asserts that knowledge of reality is possible only by denying the *absolutistic attitude.*

We may notice that the superposition principle of quantum mechanics provides an illuminating example of the *Syadvada* mode of description. Let Kets $|\alpha'>$ and $|\alpha''>$ be the different eigenstates of an observable α for a quantum mechanical system. Let $P> = |\alpha'> + |\alpha$, we have the *Syadvada* mode of description :

(1) System is in state $|\alpha'>$

(2) System is not in state $|\alpha'>$, but in $|\alpha''>$

(3) System is both in state $|\alpha'>$ and $|\alpha''>$ represented by the mixture $|\alpha'><\alpha'| + |\alpha''><\alpha''|$

(4) System is in an inexpressible state represented by $|P> = |\alpha'> + |\alpha''>$

(5) System is in an inexpressible state and in state (1), represented by $|\alpha'><\alpha'| + |P><P|$

(6) System is an inexpressible state and in state (2), represented by $|\alpha'><\alpha''| + |P><P|$

(7) System is in an inexpressible state and in (3), represented by $|\alpha'><\alpha'| + |\alpha''><\alpha''|P><P$

Syadvada asserts that a thing is "A", and it is also "not A" and both "A and not A", and so on. *It is an exhortation to investigate reality from all different possible viewpoints.* It is not a doctrine of indifference or passive acceptance of statements and also their negative. It is just the contrary. It demands our ascertaining the conditions, the coordinate frames as it were, under which a thing is "A", the (different) conditions under which it is "not A", conditions under which it can be both "A" and "non-A" and so on.

An oft-quoted illustration of *Syadvada* is the dialogue between Mahavira and his favourite disciple Gautama [Nathumal Tatia, *Studies in Jaina Philosophy* (1951), 22-23]:

Are the souls, O Lord ! eternal or non-eternal?

The souls, O Gautama ! are eternal in some respect and non-eternal in some respect.

With what end in view, O Lord ! is it said that the souls are eternal in some respect and non-eternal in some respect?

They are eternal ! O Gautama, from the view-point of substance, and non-eternal from the view-point of modes. And with this in view it is said, O Gautama ! that the souls are eternal in some respect and non-eternal in some respect.

Is the body, O Lord ! (identical with) the soul or is the body different from it?

The body, O Gautama ! is (identical with) the soul as well as it is different from it.

Unlike *Syadvada,* in Aristotelean logic a thing is either "A" or it is "not A". It cannot be both "A" and "not A" at the same time. Here the main concern is an examination of a thing from one particular standpoint, and not from all different standpoints. A Jain logician may contend that this is a meaningless effort. Any meaningful examination involves more than one standpoint. A thing can never be examined twice from an *identical* standpoint, for, if nothing else, at least the two instants of observation are different. Nothing is exactly repeatable. But in asserting this, we ignore the fact that differences between *relevant aspects* of the two (different) situations may be so small as to be negligible in practice. *Repeatability is the essence of scientific observation.* It is possible to think, but I am not competent to judge, that the *Syadvada* logic did not particularly encourage quantitative observation. Its emphasis was on philosophic enquiry.

[Reference to Aristotle's logic brings to mind the $4 \times 4 \times 4 = 64$ moods of syllogisms. (Every syllogism consists of three propositions). Of these 64 moods only 24 represent true syllogisms. [e.g., Jan Lukasiewicz, *Elements of Mathematical Logic* (1963)]. There is here a curious coincidence (numerological) with the genetic code. The code has three "letters", each letter representing one of four nucleotides. The $4 \times 4 \times 4 = 64$ possible combinations generate 20 amino acids. Adding the three 'nonsense' triplets the number is 23.]

Ethical Truths : Gandhi's "Experiments"

I said earlier that scientific truths and ethical truths are not contradictory but complementary. There can be no science without ethics and an ethical society. Equally, in the modern world there can be no ethics without science. It seems that the most significant ethical lesson of science is that "experimentation" in ethics is as necessary for its development, its practice and philosophy, as it is for progress of natural science. And the method of ethical "experimentation" is *Ahimsa.*

Mahatma Gandhi gave to his autobiography the title : *The Story of My Experiments with Truth.* He wrote (in 1926) "What I want to achieve—what I have been striving and pinning to achieve these thirty years—is self-realization, to see God face to face, to attain *Moksha* (salvation). I live and move and have my being in pursuit of this goal". The experiments which he narrates "are spiritual, or rather moral; for the essence of religion is morality". And he says : "I claim for them nothing more than does a scientist ... I have gone through deep self-introspection, searched myself through and through, and examined and analyzed every psychological situation. Yet I am far from claiming any finality or infallibility about my conclusions. One

claim I do indeed make and it is this. For me they appear to be absolutely correct, and seem for the time being to be final... And so long as my acts satisfy my reason and my heart, I must firmly adhere to my original conclusions".

In the concluding chapter of the autobiography Gandhiji says : "My uniform experience has convinced me that there is no other God than Truth ... and ... the only means for the realisation of Truth is Ahimsa ... After all, however sincere my strivings after Ahimsa may have been, they have still been imperfect and inadequate... But this much I can say with assurance, as a result of all my experience, that a perfect vision of truth can only follow a complete realisation of Ahimsa". And he continues : "I must reduce myself to zero. So long as a man does not of his own free will put himself last among his fellow creatures, there is no salvation for him. Ahimsa is the farthest limit of humility".

There is a chapter with the title, *Face to Face with Ahimsa.* This refers to the first *Satyagraha* in India initiated by Gandhiji after twenty one years of "preparation" in South Africa. Writes Gandhiji about his meeting, early in 1917, with the indigo cultivators at Champaran (Bihar) : "It is no exaggeration, but the literal truth, to say that in this meeting with the peasants I was face to face with God, Ahimsa and Truth".

Ahimsa is pure selfless love for every human being, and indeed for every living creature. It is non-injury in *mind, word and deed.* Action which does violence to one's conscience, to the little voice within the inner voice, is a departure from Ahimsa. [To kill an animal for sport is a greater fall from Ahimsa than to kill for food] *Ahimsa is a moral concept essentially.*

In the pursuit of Ahimsa the importance of *Syadvada* has been emphasised by Gandhiji. He says : "[But] all my life through, the very insistence on truth taught me to appreciate the beauty of compromise. I saw in later life that this spirit was an essential part of Satyagraha". "...Without Ahimsa it is not possible to seek and find truth ... As a coward, which I was for years, I harboured violence. I began to prize non-violence only when I began to shed cowardice .. The path of true non-violence requires much more courage than violence", says Gandhiji.

Gandhiji's experiments are spiritual, ethical experiments. The underlying basis of morality is self-control or self-conquest through self-suffering. "Liberation from the bondage of the self constituted the only way towards a more satisfactory society", observed Einstein. It is generally recognised that ethical truths have little meaning if there be no *self* (mind or soul) as distinct from the physical body. To say this is not to imply that the individual self physically survives dissolution of the body : (...it is morally necessary to assume the existence of God", observed Kant.).

The feeling or *demand* within every individual to discover one's *Swadharma* or duty, one's purpose in life—how so much this demand may wane temporarily—must be recognised as a fact of experience, a truth. The discovery of *Svadharma* is greatly helped by knowledge and reasoning but, ultimately, it transcends reason. Reason and therefore science, cannot provide answer to the questions : To what end? To what purpose? It can only lead to an infinite regress.

SCIENCE IS OBJECTIVE : SCIENCE IS NOT ENOUGH

The attitude towards science of the great pioneers of the scientific revolution—Galileo, Kepler, Newton—was that to do science was akin to rendering divine service. The Holy Bible was the First Book of God. The Second Book of God was Nature. This Book was written in the languge of mathematics. To decipher this Book was to worship God. Newton says in the *Principia* (Book III) that the "beautiful system of the sun, planets and comets could not be born from mere mechanical causes". It could only proceed from "the counsel and dominion of an intelligent and powerful Being". Newton believed that God would have to intervene from time to time to maintain stability of the solar system. [It was Laplace, who a hundred years later demonstrated, availing of developments of mathematical ideas and techniques, that such divine intervention was unnecessary]. But despite all this, it was Newton's *Principia* which laid the foundation for the autonomy of science. He says : "He (God) is omnipresent not *virtually* only, but also *substantively;* for virtue cannot subsist without substance. In him are all things contained and moved; yet neither affects the other : God suffers nothing from the motion of bodies; bodies find no resistance from the omnipresence of God. It is allowed by all that the Supreme God exists necessarily; and by the same necessity he exists *always and everywhere".* The crucial assumption that "God suffers nothing from the motion of bodies; bodies find no resistance from the ominpresence of God", was a declaration of *objectivisation* of natural science.

The gradual elimination of the supernatural and occult from explanations of natural phenomena was greatly encouraged, in the early stages, by the striking success of mechanical laws to account accurately for the motions of the planets, moon, and comets.

Today we take objectivity of science as synonymous with science itself. The reign of reason is supreme in science. [We are, of course, thinking of science as such, and not its applications which often time are totally devoid of reason.] Whenever there is a discrepancy between theory and experiment, we seek to modify the theory, and not attribute the discrepancy to any supernatural cause or agency. And the domain of science is continually expanding, extremely rapidly, as we all know. Yesterday it took the atom within its folds. Today it is the gene, the sub-atomic particles, and galaxies situated at the very limits of the Universe. Tomorrow it may be the brain; and what not ! It seems as if autonomous science will soon—some day—encompass, and engulf, *everything.* But what about the *psyche,* the "I"?

In a scientific description of nature (including man) there is no place for : "To what purpose"? To what end or goals? Astronomy tells us much about the stars, but to the question "What purpose do the stars serve?, its only answer can be "No purpose whatever". Any other answer *within* astronomy, within natural science, would be absurd.

The exclusion from natural science of subjectivity, that is, "I", is total. Within the strict confines of natural science there is no place for *self, moral truths, love, beauty* and *God.*

The basis and strength of science is its objectivity. Science is alien to purposes and goals. It admits no arguments which smack of any teleonomy. Yet the very

pursuit of science—choice to devote one's life to science and not to something else—is a moral decision. Science is objective, but love (or hate) of science is subjective. Science is *causal.* It is deterministic. But to the individual freedom of choice is a fundamental fact of direct personal experience. As H. Poincare' said : "It is just as impossible not to act as a free man when we act than it is not to reason as a determinist when doing scientific work ... We can hope that ... to infinite intelligence the two attitudes ... would seem equally legitimate ..."

The objective world of science and the subjective world of personal experience appear as two entirly different worlds.

The world of science has "room for everything, but none for man" (A. Koyre). This is deeply frustrating. It is agonizing. People carried away by the overwhelming success of science, or rather technology, tend to believe that *what is not in science is not there at all : it does not exist.*

And yet the crisis is of our own making. It is a result of our own "forgetfulness". The objectivity of science is secured by excluding from its domain all subjectivity. That is the definition of the methodology of science. The exclusion of the "I" from science is the convenant between science and "I". The roots of the present crisis of (Western) man lie in wrongly conceiving that what cannot be described by science—what is not within the perimeters of science—is necessarily contradictory to science (and therefore non-existent). It is a misplaced case of the domination of Western mind by Aristotlean logic.

What we need to recognize is that *reality* has not one facet but many. Science is one facet. The different aspects of reality are complementary to one another; and not contradictory. This approach is characteristic of the *Vedantic* thought. Let me quote Erwin Schröedinger from his great little book, *What is life* ? (1944) :

> "So let us see whether we cannot draw the correct, non-contradictory conclusion from the following two premises :
>
> (*i*) My body functions as a pure mechanism according to the Laws of Nature.
>
> (*ii*) Yet I know, by incontrovertible direct experience, that I am directing its motions, of which I foresee the effects, that may be fateful and all-important, in which case I feel and take full responsibility for them.
>
> The only possible inference from these two facts is, I think, that I—I in the widest meaning of the word, that is to say, every conscious mind that has ever said or felt 'I'—am the person, if any, who controls the 'motion of the atoms' according to the "Laws of Nature".
>
> "In itself, the insight is not new. The earliest records to my knowledge date back some 2,500 years or more. From the early great Upanishads the recognition *Athman=Brahman* (the personal self equals the omnipresent, all-comprehending eternal self) was in Indian thought considered, far from being blasphemous, to represent the quintes sence of the deepest insight into the happenings of the world. The striving of all the scholars of Vedanta was, after having learnt to pronounce with their lips, really to assimilate in their minds this grandest of all thoughts".)

To disregard the complementarity of scientific and ethical truths—the complementarity of matter and mind, of body and soul—can lead only to de-personalization

and de-humanization of life. The highest type of scientific activity is not possible without a supreme faith in science and in man. This is a moral quality. There is no inherent contradiction in the same person being an intellectual giant and a spiritual pigmy, but in real life it is most unlikely. When asked (during a serious illness) whether he was at all afraid of death, Einstein said : "I feel such a sense of solidarity with all living things that it does not matter to me where the individual begins and ends". And he said, "There is nothing in the world which I could not dispense with at a moment's notice". How close to Gandhi are the ethical convictions of Einstein ! He regarded Gandhi as "the greatest man of the age".

The most significant lesson we can learn from the marvellous developments in atomic physics in our century is not to be misled by apparent contradictions, but try to understand the complementarities underlying them. The great lesson we owe primarily to Niels Bohr is that we must learn to take the complementarity approach seriously not only in science but in life. And the philosophy of complementarity is essentially the philosophy of *Syadvada* and of the *Upanishads.*

It is time I said something about complementarity itself. I have used the word frequently. I must admit I have not used it consistently. It is because the concept is not an easy one; it is entirely novel at any rate in the modern context; and my thoughts are not clear. That makes the subject interesting, but also irritating (not only to others but to me equally).

In speaking of the complementarity of two aspects or viewpoints, an important element is that the situations under which the two aspects occur are *different* in some essential respects; Complementarity of the two aspects implies some irreducible element of incompatibility between them. This is necessary.

The complementarity principle has emerged, in the modern context, from the study of atomic phenomena. The complementarity of the wave and particle aspects of matter is well-known. The two aspects are incompatible. An experiment which demonstrates the wave aspect would automatically exclude demonstration of the particle aspect; and vice-versa. Why so? It arises from an interaction, inherent in the nature of thing between a system and the measuring instrument. The interaction cannot be eliminated even under ideal conditions. It cannot be reduced below a certain minimum limit, defined by the Plancks's constant, for any conceivable experment—or "thought experiment". The interaction disturbs the state of the system under observation. An experiment which provides some information about an atomic system, inevitably destroys (in general) some other information which we had about the system from an earlier experiment on the system. We cannot accumulate information indefinitely, because of an unavoidable interaction between the system and the measuring device, and the accompanying disturbance of the state of the system. This is totally different from the situation in classical physics. If interaction between a system and the measuring device could be *completely ignored,* made zero—as was the assumption in classical physics—then, in principle, the measuring instrument becomes redundant. Not so in quantum mechanics! The complementarity principle is forced upon us because there can be no measurement without a certain minimum interaction; and the experimental arrangements for determining different properties of an atomic system are, in general, *incompatible* with one another.

In fact, if we could think of an experiment which is *inherently* incapable of giving us information about some obvious, characteristic property of the system, then such an experiment is likely to reveal unexpected features of the system. This in a sense is the essence of complementarity mode of thinking in physics. As is well-known, according to von Neumann and E. P. Wigner, the conceptual problem of *measurement* in quantum mechanics brings to the fore a role of human consciousness which has no analogue is *classical physics.* But I shall not pursue this here.

There are levels of Complementarity—a hierarchy. To take a rather trivial evample the particle and wave aspects of an electron in an atom are complementary; and there is also the complementarity of the particle and wave aspects of the atom which contains the electron. *Physics* (objectivity) and *psyche* (subjectivity) are (perhaps) complementary. May I in this context refer to the monograph by C. G. Jung and W. Pauli : *The Interpretation of Nature and the Psyche* (1955).

To sum up : our conclusions are simple :

Firstly, there should be effective and deliberate opportunities for interaction between science and philosophy (understood in its widest sense). This is likely to be of immense mutual benefit. Science is enough. In promoting interaction between science and philosophy the Universities and the Academies have a special obligation. A chair in philosophy of science is an obvious suggestion.

Secondly, the complementary mode of thinking should have a much wider scope, than at present. It holds great potentialities not only within science, but for everyday life, and in human affairs generally. Indian philosophic thought (particularly *Syadvada*) is of great relevance to understanding and future development of the complementarity paradigm.

Thirdly, the notion of truth—in mathematics, science, or ethics—is *regulatory. There are no absolute truths. Truth is a guide to action to ceaseless striving.*

To pursue truth in all its varied aspects of which the ethical is doubtlessly the most important—with zest, courage and dedication to the best of one's ability and strength, is man's highest duty and obligation. That is the greatest lesson science holds for us. That is also the greatest need of the world today.