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THE VALUE OF PHYSICAL SCIENCE IN A MODERN COMMUNITY

PROF. D. J. FOURIE, M.Sc., D.Sc.

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1. *Historical background.*

Man considers himself the prince of creation. This was the case even before his most recent triumphs and achievements were realised. By the long way of evolution he finally reached the status of *Homo sapiens.* It seems as if the peak of knowledge has now been attained and that man has become godlike. But actually it is only the beginning of man as *Homo ignoramus.* We never before realised how little we really know about the wonders of creation.

To appreciate the extent of our present scientific knowledge, it is necessary to recall certain events in the history of the past 24 centuries.

We can trace the first signs of physical science back to Plato and Aristotle who lived about 400 years B.C. In his own words, Plato's method of approach to a problem was as follows:- "I presuppose a certain principle, that stands firm according to my judgement. Then I take as true all that agrees with it, although it may not have any relation, and all that disagrees is rejected as false."

In this plain statement lies actually the difference between physics and metaphysics. Metaphysics is based on reasoning and the accentuation of differences, while physics has experiment and agreement as basis.

The latter part of the Renaissance, i.e. about 1500 A.D., marked the end of the "Dark Ages". From it arose the new ideals of man namely confidence and curiosity. The following example shows clearly the change of attitude of man towards his problems. Before this time Copernicus for instance had supported the views of Aristotle only to make his own work acceptable. A century later Galileo demanded that his theory should be accepted on its own merits of simplicity and usefulness, without any considerations of questions of faith and salvation.

Galileo showed by means of experiments that the theories of Aristotle were faulty. He was however a prophet without honour to his homeland. Because of the suppression of his works in Italy, he published them in Holland.

His letters (1613—1615) show clearly that he believed that the concept of God contains all the laws of nature and that occasional glimpses into these laws, which the serious student obtained through research, were proof and direct confirmation of the Deity and were just as valid and as great as those of the Bible. He wrote: "The Holy Spirit intended to teach us in the Bible to go to heaven, not how the heavens go."

The war of authority against science just like the war of ignorance against knowledge has not diminished since the days of Galileo. Today the Russian scientists must reject well-established theories on the grounds of conflicting ideological doctrines. In 1944 a leading Russian scientist stated: "Scientists in all branches of knowledge cannot and should not remain indifferent to the ideological struggle between Communism and Capitalism". Hitler also banned the works of Einstein because the latter was a Jew.

With the appearance of Newton 44 years after Galileo, a new era of philosophy emerged and scientists started to exchange views through societies, in journals and in debates. Science then became welldefined, precise and international.

During the period 1900—1925, physical science received a new stimulus through the introduction of the quantum theory by Max Planck in 1900. Einstein, Rutherford and Bohr followed up with farreaching applications of the new theory and so became champions of a revolution that transformed physics fundamentally. They changed the picture of the atom and were followed by Heisenberg, Schrödinger, de Broglie, Dirac and others, who recast the old concepts into their modern forms. In 1925 Heisenberg stated: "I am going to attempt to find the foundation for a mechanics of the quantum theory". This quantum mechanics was the axis round which the enormous progress in physics during the past 35 years has turned.

Today we are again experiencing a new revolution in physics — we are standing on the threshold of the nuclear era

2. *Spiritual science and pure science.*

In general the sciences can be divided into two main, basically different groups. The first group embraces the spiritual sciences that are ethically, lyrically and temperamentally orientated. It includes conceptions such as honesty, loyalty, love, reliability, character, etc. It contains much substance but is not accurately definable. It is for instance not possible to give

an exact definition of love neither is it possible to find a unit for its measurement. Love cannot be measured, and so with all other ethical concepts. These abstract qualities probe the innermost depths of man's spirit, his soul — make life worthwhile and supply the laws for co-existence.

On the other hand we have the pure sciences which have to do with measurement and numbers and clearcut concepts. It uses differential equations and integrals, vectors, force and power, atomic weights, temperature curves, bloodpressure and X-ray photographs with all their variations, and checks and balances. The concepts here can be defined exactly and are measurable by actual units. They stimulate human welfare; provide aids and means for supplying work, bread and all temporary needs for the individual, and wealth, power and security for the state.

The expression of the spiritual world is found in literature, the arts, moral laws and the culture of the community, while the visible results of science are seen in buildings, factories, towns, transport, the radio, medicine and the thousand-and-one day to day technological requirements of man.

The object of science is to predict the workings of nature and so to control them, and for the poet it is self-realisation, the proclamation and ennoblement of man's own spirit. The two ways of thought are therefore complementary not contradictory. Both concepts are to some degree co-existent within each individual.

Although these two activities of the human intellect and spirit grow in different directions and the one probably faster than the other, both originate in the same needs of the human being. There can be no culture without pure science. Both have their value and the one cannot exist without the other.

This view and approach to the problems of knowledge must be advocated in the schools and at the universities. Education, however, cannot be measured on a fixed scale and therefore faults can only be detected when it is usually too late to rectify them. We can only trust that the foundation we hope to lay here will be solid and crackproof so that it will withstand the destructive force of the spirit of the times.

3. *Scientific method*

Science never pretends to explain natural phenomena with

absolute finality. In this connection Mach said:- "Let us early get used to the fact that science is unfinished, variable".

The formulation of scientific laws by man is neither eternally true nor unchangeable. There are limits to the validity of each law.

Although the result of a scientific analysis may be a mathematical formula that can be applied to a great many instances, it sometimes rises out of an illogical sequence of observations. The scientist proceeds through his problem like an explorer through a jungle, sensitive to every sign with every faculty of his being. H. Smyth, an American nuclear physicist, puts it as follows:- "the research man may often think and work like an artist, but he has to talk like a bookkeeper, in terms of facts, figures and logical sequence of thought."

Most people today would probably agree with Tolstoi, who, in the early years of modern science, stated that:- "A person cannot know everything because there are innumerable facts. By the choice of knowledge, usefulness, practical and moral necessity are being taken into consideration."

On the other hand, most true scientists of today will however support Poincaré when he says:- "The scientist does not study nature because it is useful; he studies it because he delights in it, and he delights in it because it is beautiful. If nature were not beautiful, it would not be worth knowing, and if nature were not worth knowing, life would not be worth living. Of course, I do not here speak of that beauty which strikes the senses, the beauty of qualities and of appearances; not that I undervalue such beauty, far from it, but it has nothing to do with science; I mean that profounder beauty which comes from the harmonious order of the parts and which a pure intelligence can grasp. This it is which gives body, a structure so to speak, to the irridescent appearances which flatter our senses, and without this support the beauty of these fugitive dreams would be only imperfect, because it would be vague and always fleeting. On the contrary, intellectual beauty is sufficient unto itself, and it is for its sake, more perhaps than for the future good of humanity, that the scientist devotes himself to long and difficult labors."

It is also true that we would have very little of the modern practical utensils if it were not for a few earlier devotees, who died poor and who never worried about the usefulness of their

work. According to Mach these devotees have saved their successors the trouble of thinking.

Years of toilsome and often wasteful effort may be hidden behind a few elegant paragraphs of scientific report. How fortunate for the progress of science that individual scientists do not permit themselves to become discouraged by this wide prospect of lengthy struggle — even if many do achieve their peace of mind usually only by a whole-hearted devotion to the narrower, day-to-day progress of their work.

Now if scientific knowledge can be sought in many ways, it is not because science is a game, a systematic delusion or the persuit of conception and memory. It is rather because nature is so rich in matters to be learned and scientists so apt at finding ways to learn them.

What now is science actually? Let us consult some great masters of this art.

Einstein:- "The object of all sciences is to co-ordinate our experiences to bring them into a logical system".

Bohr:- "The task of science is both to extend the range of our experience and to reduce it to order".

Schwab:- "The object of physical sciences is to reduce the natural phenomena to unalterable forces".

James B. Conant:- "Science is an interconnected series of concepts and conceptual schemes that have developed as the result of experimentation and observation and are fruitful of further experimentation and observations".

Now, keeping these definitions in mind, we can try to analyse the scientific method and the achievements of the physicist.

Firstly, we compare the work of the physicist to that of the anthropologist. The physicist works in a laboratory with instruments, while the community is the laboratory of the anthropologist. The physicist is an explorer in a universe of events and phenomena, attempting to find their pattern and meaning. The anthropologist may succeed in decoding the original problem, bringing back an account of the political and family organization of the people he is studying, also their esthetic values, religious beliefs and practices, their economic methods and so on. Per-

haps he will then be able to reconstruct the history of that people.

From a multitude of observations and facts those are sorted out which have a change of reappearing and which can be simply ordered. These are called the simple facts. Scientists through the ages look for these simple facts at first in the endless vastness of the universe and later in the infinitesimal constituents of matter.

The scientist believes that nature works according to mathematical laws and that the observations are explained when he finds the mathematical law relating to these observations. Above all there is a type of law most eagerly sought which says: "This function of the variables under given conditions is always constant". A great aid to speedy understanding and manipulation of concepts is the fact that mathematically formulated ideas can be expressed symbolically in equations. Here the interpretation of words disappears; it becomes easy to communicate arguments and results clearly to your fellow-men, and they are encouraged to draw further conclusions about the relationship between observables.

Scientific laws and controlled experiments do not directly deal with real bodies but with abstractions in hypothetical pure space with properties of its own, in a world which we can manipulate at will. Our mathematical world is justified and taken seriously by physical science only in so far as it does yield new knowledge about the real world around us. The symbols and equations of the physicist bear the same relations to the actual world of phenomena as the written notes of a melody do to the audible tones of the song itself.

The task of the sociologist is the most difficult, because his material is human beings — people who differ and people who change i.e. very complex material. It is a fact that history never repeats itself. Therefore to choose the fact that will re-appear i.e. the method, is very difficult here and we know that in sociology many methods are used and few results obtained.

Very seldom in sociological problems do the properties of the constituent factors provide an adequate or complete account of the whole. Democracy for instance, like other forms of group living, cannot be defined adequately by means of isolated elements of conduct, rules or institutions; it is the larger pattern of group life and the group atmosphere which determines how society is to be classified.

Physical theory correlates varous facts in a logical, easily realisable structure of thought. Physical concepts are often represented as a model e.g. the Bohr model of the atom. In modern science the problems are more and more removed from the realm of common experience and so it has also become necessary to enlarge the kit of tools with which to grasp and comprehend phenomena. The nuclear atom serves as a particularly striking example of the breakdown of the more naive types of understanding.

Through the theory, right or wrong, the attention is drawn to the phenomena and the attempts of various scientists are co-ordinated — truth arises more easily from error than from confusion. Although a theory can be modified or changed, it is seldom bluntly rejected. It more often follows a steady process of evolution and the work of the past is never in vain.

Rutherford put it in clear language: It is not in the nature of things for any one man to make a sudden violent discovery; science goes step by step, and every man relies on the work of his predecessors.

The idea of objectivity in science is universally accepted. To show what it actually means, we can quote Bertrand Russel:- "The kernel of the scientific outlook is the refusal to regard our own desires, tastes, and interests as affording a key to the understanding of the world". Louis Pasteur held the same views in the following passage:- "When you believe you have found an important scientific fact and are feverishly curious to publish it, constrain yourself for days, weeks, years sometimes; fight yourself, try to ruin your own experiments, and only proclaim your discovery after having exhausted all contrary hypotheses. But when after so many efforts you have at last arrived at certainty, your joy is one of the greatest than can be felt by the human soul".

Poincaré believed that the search for truth should be the goal of the scientist's activities. But to seek the truth it is necessary to be independent. If however we wish to act and be strong, we should be united. This is why many fear the truth; they consider it a cause of weakness. Yet truth should not be feared for it alone is beautiful.

Scientific truth is not the same as moral truth. But they cannot be separated. To find both it is necessary to free the soul completely from prejudice and passion; it is necessary to attain absolute sincerity.

Ethics and science have their own domains, which touch but do not interpenetrate. The one shows us to what goal we should aspire, the other, given the goal, teaches us how to attain it. So they can never conflict since they can never meet. There can be no more immoral science than there can be scientific morals. The universal harmony of the world is the source of all beauty.

4. *Science and religion.*

We have already seen that the object of science is to predict nature and so to control her. There are however phenomena that man can neither foretell nor control, and probably never will.

One single irregularity that disturbs the harmony of our solar system can mean its end. A comet for instance appearing from the unknown depths of the universe may cross the orbit of the earth and destroy our planet completely. Seneca saw this catastrophical happening as follows:- "A single day will see the burial of all mankind. All that the long forbearance of fortune has produced, all that has been reared to eminence, all that is famous and all that is beautiful, great thrones, great nations — all will descend into one abyss, will be overthrown in one hour".

It is on points like these that science and religion touch. Boltzmann once wrote:- "War es ein Gott, der diese Zeichen schrieb, die mir das innere Toben stillen, die Kräfte der Natur rings um mich her enthüllen".

According to Kant our experience is bound by space and time but the spirit is free. Therefore at the point where experience and experiment fail, the search for truth can be continued through faith.

The thirst for concreteness, which is a feature of the human mind, explains the frequent use of models within science itself and for the most primitive type of everyday explanation. We find it symbolised in the belief of the ancient people of India that the earth was supported in space on the backs of gigantic elephants.

The usefulness of a model depends on how far it can represent the experience correctly. In physics today the idea of accuracy replaces the idea of truth. The "equivalence idea" of Einstein namely that matter and energy are interchangable,

cancels in general the idea of the indestructability of matter. Clear models of the reality must be taken into the abstract when the process of science demands it.

Theology has to do with supernatural realities. To speak scientifically about this subject, the totally strange circumstances must be represented by a perceptible picture. Theology often makes use of human model representations, whose power cannot be denied, although an interchangable of model representation and supernatural reality could easily be fatal. As an example we can think of the many metaphors in the Bible and the various interpretations or misinterpretations that have been given to them.

The change from a Bohr model to a Schrödinger mathematical model of the atom is an entmythical process. The correctness of dogmatic models cannot easily be tested by experiment; their validity shows rather in the degree of resonance that such model thoughts create in people's hearts. Faith should not be challenged by model representations in physics or in theology, while this will aid the interchange of model and reality.

Real tolerance grows from the realization of the fragmentary nature of human thought, and it creates a candour and appreciation for other ways of thought.

Since the mind of man is not divided into separate compartments, and since science exists as a complex of conceptual schemes propagated through the minds of men, we see that the one must interact with the other. Science must influence the whole cultural pattern of a society and in turn be shaped by it. It is only natural that,for example, Galileo's argument on the motion of heavenly bodies, like the theories of his adversaries also, should be coloured by, and again be expressed in, contemporary theology.

5. *Science and politics.*

Students and lecturers in science can be classed into three groups:-

(i) The largest portion of them find public matters strange and incomprehensible. Their world and their human outlook are orientated according to their own private life.

(ii) The second group is intelligent enough to see the political

connection and common problems but they do not take part in public matters. They rather use their knowledge for their own benefit.

(iii) The last group is usually a small one and they feel themselves responsible for their community and so become concerned with politics. Among these are students who are deeply concerned about the future of their country and their people. We also find here a negative variant namely the always active minority that burst out of the strict concentration of the study by doubtful activities as mimics and who with sterile honesty in their pseudo parliamentary play, undermine the true value of the student and bring his behaviour under suspicion.

A scientific approach can be of great value here. An honest independent search for the truth by each individual student will clear the troubled waters and restore confidence not only in himself but also in the institution he is representing. This approach will place his way of handling difficult situations on a firm basis that will draw respect from the personnel and fellow students.

6. *The future.*

The task is by no means finished. Will it ever be? We who have followed the development of physical science from its infancy in ancient Greece to its flowering in our day, and who have seen that every Ptolemy is challenged by a Copernicus, that every Kepler and Galileo must be made meaningful by a Newton ,that every Dalton is eventually transfigured by the work of a Mendeleef or a Bohr, are fully prepared to accept the view of science as an ever-widening spiral, an endless quest for wider horizons. As long as there is thought there can be no end to the adventures of the mind.

The nuclear age, which we are now entering, may lead us to happiness or it may help us to end the short history of our species. All governments are in some or other way developing plans for the construction of nuclear engines for industry as well as for the destruction of hostile areas. Salvation and disaster are not reached by separate roads so that we may simply choose one and avoid the other: They both lie at the end of the same path, the choice being within ourselves.

How can a physics department at a university or college assist in achieving the ideal of a prosperous and happy community?

(i) It can bring the knowledge to the students in such a way as to be easily digestible and also tied to material concepts that can easily be understood.

(ii) It can stimulate progress and interest by fundamental research, that will lead the students to their own original achievements.

(iii) It can be a shining light to the community by participating in country-wide or even world-wide scientific activities. Public lectures on novel topics could be arranged. Refresher courses for teachers of science could be organized. In short, it could act as a transmitting station that will radiate scientific knowledge to everyone in the community who wishes to make himself a good member of the modern civilized world.

Most of the matter contained in this manuscript was taken from the following publications:-

(i) Introduction to concepts and theories in physical science. — Holton.

(ii) The value of science. — Poincaré.

(iii) Physikalische Blätter. 1960.

(iv) Behavioral Science. January 1960.