A CRITICAL ESSAY ON THE HISTORY OF SCIENCE

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1 THE HISTORICAL ASPECT OF PRESENT SCIENCE

The activity of science, by its very nature, must be involved in past and future. From the past comes the accumulated knowledge, the techniques and the accepted ideas which constitute the basis for the activity of the present moment. Science is involved in the future, on the other hand, because research depends upon expectancy or anticipation. We can picture the situation either as science moving through from past to future states, or as a "present moment" of relatively coherent activity and experience in which the past is transformed and the future fulfilled. Since we cannot separate the past and future states of science from the science of the present moment, the first image is misleading. In some way or other, science makes its own past and future by what it is in the present moment. If we adopt the second image, we must not, of course, commit ourselves to the extreme view that the science of any one present moment completely determines its past and future conditions.

We will adopt the notion that the present moment of science—at any period of history—is coherent enough to exert some kind of influence upon the traces of the past, and to influence its own future condition. We can picture to ourselves "present science" as a moment of activity into which enter antecedent components and from which arise some of the antecedents of future "present sciences". What enters is seen as "sources" or "origins", and future science is in apprehended through expectancy. Present science cannot provide all the antecedents of future science—for in that case one would have to talk of a continuing present moment throughout the whole of science, which is completely contradicted by the variety of evidence for discontinuities: extraneous influences, changes of method and so on. The boundaries of present science are established in three ways. First, there is the selection of what is scientifically correct by the consensus of opinion. Secondly, there is the implicit selection involved in scientific inheritance and in generally accepted aims and hopes for the future. Thirdly, there is the selection of the members of the scientific determined, in part, through educative procedures. Together with all of this is a continuing process of interpretation which consists, in general, of a reflective activity within science. This makes judgements upon the content of science that go beyond simple correctness, it seeks for self-integration. Finally, there is also the present moment of science as a scene of *action.* Here, above all, it cannot be divorced from the 'total present moment of the society in which it exists. The scientific community has a variety of roles as a sub-group of the total society. In the present age, human drives of all kinds are involved in science as action.

The boundaries of present science

Further, present science is defined by two kinds of boundary. On the one hand there is the selection of *membership*. Here belongs the determination of the correctness of theories and experiments, as well as the selection of members of the scientific community, which is partially a self-selection. On the other hand there is the selection of *sequence.* These two usually operate together.

Acceptance and rejection on the pan of the community of scientists decides what theories shall be allowed to survive. (An individual scientist has to recognise the importance of "killing babies" in his production of hypotheses.) At any time, there may be uncertainty about the states of a theory, or overt conflict, but this is assumed to be restricted to a *temporary* phase in the science. In time, uncertainty dissolves and science is consolidated with an accepted body of concepts and applications.

Even where one can find no overt selective action, still a path is being selected. Thus, for example, tensor calculus has come to be the accepted tool for cosmologists; whereas it is but one of a large number of mathematical techniques applicative to cosmological problems. This probably arose because of the association of tensor calculus with the accepted theories of Relativity of Einstein.

Recently, far more elegant mathematical formalisms have been applied. A prime example is the method of "differential forms" as developed by Carton. Eddington pointed out years ago that the tensor calculus must leave out the properties of spin, and that there is a more fundamental "spinorial calculus". He also many times argued that every formalism is like a fishing net—one can only catch fish which are larger than the holes!

The self-selection of science spreads out into education and the transmission of knowledge and techniques from generation to generation. It is the source of continuities of patterns of thought and action whereby the active science of the time becomes the interpreter of its own history. It is interesting to reflect that the same process of transmitting knowledge and techniques into the future also operates on the events of the past to give them a new and often radically different meaning. In teaching young people about relativity, the status of Newton's theories changes.

Inheritance and hopes for the future reflect a general operation whereby the actual succession of actions is selected. Here enter all the problems of integration. Since science is complex, a multitude of sequences operate in a loosely cohering present moment. The diversity of membership leads to an incoherence of sequence, and hence to a lack of a common experience.

The present moment for the scientific community

The problem posed by the disintegration of the present moment of science into an incoherent set of isolated sequences is widely recognised to-day. We see the growing interest in ways of improving communication, and in bringing together the membership of present science. It is now becoming clear that the journals, long assumed to be representative of the present moment of science, are no longer so.

Present science lives in the informal encounters of research scientists who come to know the significant content of scientific papers months, and even years, before their publication,* The "specious present" of the journals already belongs to the past. This must be so, because a scientific paper to-day is a *trace of the past.* The scientist has moved on, but his work remains. Here it is pertinent to draw attention to the recent criticism of the scientific paper on the grounds that it *falsifies history* In not reporting the actual features of the piece of work; instead, it presents a formalised version which aims at being a-historical.**

*C.f Price, "The Scientific Formulations of Science Policy" *Nature, 206,* p 236 ". . such a change makes mockery of an ideal of an external and permanent archive of science . . . this was never more than a useful . . , mythology, for science has customarily grown from its research front.

** C.F. Medewar. *"Is the Scientific Paper a Fraud?"* a broadcast talk printed in Experiment (1964) edited by Edge, B.B.C**.** Publications. "The scientific paper is a fraud in the sense that it does give a totally misleading narrative of the processes of thought which go into the making of scientific discoveries."

A research scientist will read the scientific journals in order to find out what has been done. His hope is to see how he can fit himself into the general nexus of activity. But, all the time, he is consulting the past failures of present science. Beyond the boundaries of this scientific moment lie the archives, which constitute a kind of latent memory. Chains of cross reference stretch back into the past rather as associations in the mind reach back into forgotten experiences. If most of the archives were not in oblivion, the present march of science would be choked with dead material. The perceived past is what is relevant to presen t activity.Also, the research scientist takes his cue from a sense of "trends" within the present moment. The atmosphere of scientific research, as we said before, is permeated with expectancies and hopes. More and more, the research scientist has to be aware of the movements within current science which promise a creative future. He works according to the events of tomorrow as well as according to those of yesterday.

Without this effective presence of past and future, no coherence could be perceived*—and hence there would be no coherence at all— within the present activity of science. The situation establishes a certain kind of compresence of past, future and membership which is partially dependent on how scientists *perceive* the science of the present moment. If this were not so, then we would have to hypostasize science** as some self-directing entity, carrying forward its scientific membership as an animal carries forward its component cells. On the other hand, science cannot be dependent on the perception of its membership—we have already noted how this is inadequate as a means of rendering present science coherent.

* C.f. Paul Fraisse (1964). *The Psychology of Time*—'there is order in this present, there are intervals between its constituent elements, but there is also a form of simultaneity resulting from the very unity of my act of perception " (p. 85).

' Or “society”, “history” this does not affect the argument

The image of present science

The perception of what is happening in the present involves images derived from the scientific inheritance and from projections into the future. These enter in the continuing activity of interpretation, to which we have already referred. Behind the determination of which pieces of scientific work are to be accepted as authoritatively representative of present science—for example, which, of a group of theories is to be taken as correct—there are two important processes at work. The first we have already touched upon in describing the effects of transmission on the status of past theories. It is the formation of the image of *proper science.* This we will discuss more fully in the next section. It is, however, necessary at this point to deal with the notion that the science of all periods can be characterised by scientific method.

Many have fixed their attention on the general form of successful scientific procedures, and have assumed that this form—the scientific method—entered the sphere of human action at some period, and from then on, through many vicissitudes, has gained ground and consolidated its position—especially in the last few centuries. This view is inadequate, since the scientific method can be understood as a technique—the operational view— as an attitude towards our image of the natural world—the metaphysical view—or as a basic structure of thought and action—the psychological view. Now techniques are transmitted, whereas a metaphysics or set of notions endures through recurrence according to its intrinsic power to touch simultaneously on many aspects of experience. Such a set of notions has an underlying structure which gives it an *a priori* validity. Again, structures of thought and action are social realities as well as psychological ones. They are established in societies in the organisation of activities and the integration of groups of differing function and character. Hence they are involved both in the condition of the human mind at a particular stage of evolution and in continuity and development of social structures.

The general form of scientific method discussed by the philosophers has, however, much to do with the endurance and life of the idea of a scientific method. This is clear enough from the writings of Plato, Aristotle, Aquinas, Bacon, Kant, Locke, Whewell and others. The activity of the philosophers in seeking after the general form of successful scientific procedures does indeed propagate an idea, but they also contribute to the historical character of science. The surviving material of science e.g. accepted theories—is constantly being re-interpreted by the philosophical activity.

It may be that these re-interpretations of science play little part in the actual work of scientists, but something of the same kind is done by scientists themselves. The demands of transmission make it almost inevitable that the archives be specially interpreted for ease of instruction. It is notorious how unrealistic the text-book is, and how it must give a superficial kind of coherence to "science up-to-date"—the past for present science—by glossing over the very difficulties which have a high probability of being points of creative advance in the future.* This belongs to the second process behind the selection of what is correct. Whereas the first is concerned with the *form* of science, the second is concerned with the *content* of science.

Most creative scientists have felt a link with the great scientists of the past that is more than "using" inherited material. In this domain there is a participation in a process of unceasing interpretation that is quite distinct from the accumulative and selective growth of the "time-body" of science which may be visible at any one time. This notion is -supported by the regard which scientists often have for work which, though incorrect according to contemporary standards, has expressed some living idea—thus, for example, Lamarck's evolutionary ideas are still relevant for modern research biologists.**

* C.f. Kuhn. *The Structure of Scientific Revolutions.* "Both scientists and laymen take much of their image of creative scientific activity from an authoritative source that systematically disguises—partly for important functional reasons the existence and significance of scientific revolutions ... I have in mind principally text books of science together with both the popularisations and the philosophical works modelled on them."

** C.f. the ‘Lamarckianism' inherent in modern biochemistry—e.g. the work of Hinshelwood. If one looks carefully, one can see recurring in modern biology various forms of Lamarckianism. For a biologist who was explicit in asserting the importance of Lamarck we can cite Cannon

Interaction between thinkers separated widely in time and in modes of thought and expression is possible only if there is a development of understanding that is neither localised within individuals, nor a matter of mere accumulation of knowledge and techniques, or even refinement of theory. This can best be understood if we see understanding as the link between the "inner" world of intention and the "outer" world of existence which leads to effective action. One of the most remarkable features of science—one, it must be stressed, that applies to all *kinds* of science, in *any* age, and not just the present day—is that it combines the will of man with his uncertain perceptions of the world in effective and meaningful action. By those men who go beyond science as a standardised procedure, and see its powers to connect expectations, interests and constructive urges with the existing world of actualities, science is *being created.* Without this kind of action, science would be just like cooking, which lives on through self-renewal alone! In the continuous creation of science the total human understanding of the universe, of which existing science is only the visible form, undergoes a change. From this stem re-evaluations, changes of interest which reflect some change in the structural content of this understanding. To make this rather difficult concept less abstract, reference can be made here to the radical transformation of science in this century, beginning with the innovations of J. J. Thomson, Einstein, Planck and Rutherford. Irreversible changes were made. These should be distinguished in kind. There is, for example, a great difference between the use of new mathematical techniques made necessary by relativity theory and quantum mechanics, and the change of attitude from the conception of the world as susceptible to greater and greater precision of description to the concept of indeterminate states and a relativity of description. This is supported by the manifold evidence of re-interpretations of earlier works, such as that of Maxwell, revealing similarities of structure of modern notions.*

* For example, it has been shown by Bohm that one can derive a topological space-structure from Maxwell's equations of electro-magnetism. Topological discrete spaces are of foremost interest in the science of today.

This is especially striking for relativity theory and quantum physics. They are constantly subjected to interpretations—both in terms of axioms and of formalisms. This springs from the contemporary interest in understanding the content of modern physics. There is an underlying current of uncertainty which partially explains this. On the other hand, there is also an urge to construct an integrated picture.

History and the present moment of science

It is already becoming clear in our discussion that present science is, in some sense, involved in doing as well as making history—as an *integral part of its activity.* This is largely done unconsciously — an operation on the traces of the past in transmission and selection. The perception of the present moment involves an interpretation of the past and future as well as the present. It involves scientists in situating themselves within history. What they are doing in the present moment cannot be divorced from how their work is related to that of the past, and to the possibilities of the future. Without this, present science could have no coherence. It is not, however, simply a shared perception that lenders science coherent. The coherence of science is derived from its *structure.* Science is a complexity, but it is also organized. We use here the word "structure" in a special sense to mean that property of all experience by which we discern that its complexity is organized and sometimes even more than organic. The notion of structure implies also that forms of organization tend to recur and may be recognized in situations that differ in content and appearance. The unity of structure that links the history of science with scientific activity at any given moment is an example of this correspondence.

Finally, it is becoming widely recognized that it is not enough— even if it could be achieved—to have a coherent image of science. It is more than a pattern-conforming process which has a change of content hut not of form. Science evidently does have a changing content of ideas, apparatus, people and so on. It is also an eternal object in the sense of conforming to certain general patterns of behaviour and thought; but it is more than either of these. It is an action in a present moment, and an action in a variety of "present sciences". This is its truly historical reality.

Today, we can recognize that what science can *do* has changed. Human drives have a new mediation for action in the powerful methods and ideas of modern science. Hence we can witness science harnessed to war, strategy, commerce, agriculture and entering the fields of management, education and even art. From the atomic bomb through cybernetics to kinetic art, science has entered a new phase of action. The interpretative process occurs within this complexity of action.

Action must be understood—it cannot be an object of knowledge. And for this we must understand the history of science. This will lead us to diverge from the selective procedures of scientists which give them know ledge of past science, but not the understanding which can illuminate the significance of their own actions in the present moment.

2 THE HISTORICAL MEANING OF SCIENCE

Science is always concerned with making advances. It has become for us the paradigm case of a progressive activity. In general, it is the prime example of the modern age with its keen sense of improvement directed towards the future. At the same time, it shares in the uncertainties of our historical moment. To-day, more than ever, it is concerned with self-evaluation and reconstruction.

The advance of science

What are the agreed signs of progress in science? We can put side by side the instruments of to-day and those of the last century and demonstrate unambiguously the improvement of experimental techniques, The vacuums we can achieve to-day are several magnitudes better than those attained at the beginning of this century. The same kind of comparison can be made for mathematical techniques. We could also compare the astronomical tables of Kepler—his famous Rudolphine tables which were supreme for a hundred years—with those available to-day, and we would have no doubt that the modern tables are incomparably superior. Also, many more branches of science are being studied than those conceived of two hundred years ago. The quantity of accumulated knowledge increases exponentially year by year. Further, we would say that present science solves what were the problems of the past. The present science of the nineteenth century solved the problem, for example, of the nature of chemical elements, which troubled Boyle, Prout, Bertholet, Dalton and many others over hundreds of years. That it has generated new problems in the process does not vitiate its definite achievement. We would regard this, rather, as a further sign of progress—for new questions can be asked, with an eye to their future resolution.

We extrapolate our comparison of the past with the present into the future, and surmise a future of continuing advance. Some scientists imagine a time of ultimate convergence upon a unified science—that is, a comprehensive account of everything that can be known about the universe. Thus, for example, to take a limited aspect, biochemists talk of finding the secret of life. In physics, there are those who hope for a single all-embracing theory. At the same time, other scientists will not admit of any finality, but see the future as a never ending exploration of the infinity of the universe. Some even suggest that the universe in its very nature can never be grasped in any finite comprehension and certainly not by any set of theories.*

***** C.f. Bohm *Causality and Chance in Modern Physics* "... in terms of the notion of the qualitative infinity of nature, we see that *every* law that can possibly be formulated has to have errors, simply because it represents nature in terms of some finite set of concepts, that inevitably fail to take into account an infinity of additional potentially or actually significant qualities and properties of matter" (p 116)

Up to this point, our criteria of advance have been technical—a matter of making comparison in terms of experimental apparatus, mathematical tools, branches of study and the solution of specified problems. But what renders all of these significant for science is their place in a present moment of scientific activity. The Rudolphine tables were significant for the astronomy of the late seventeenth and early eighteenth centuries. The vacuum tubes and pumps just before the turn of the century were a significant part of that present moment we call the "discovery of the electron" by J. J. Thomson.* They are not significant in that way for the present science of today.**

* C.f. H**.** Bortoft *Systematics; 2,* 4 pp. 323 f.

** Of course, contingent features of design and development are often continued mechanically into the future and significantly condition the possibilities of future present moments of science. See below, where we talk of the notion of the “perpetuation of origins”.

As for mathematics, it is well known that, beyond the boundaries of present science, lie untapped potentialities—the work of mathematicians which could, through right application, lead to major creative advances. Present science is separated from the work of mathematicians by a form of ignorance which divides its members into separate compartments and excludes a diversity of men capable of making contributions to the activity of the present moment. A change in the perception of scientists has enabled the study of topology, undertaken for more than fifty years by mathematicians, to find all kinds of application in contemporary science. Through this, we may guess how much still remains hidden. Thus, not only should we compare the past and the present, but we should also realise the limitations of the present moment of science in comparison with the total present moment of human study. Here, indeed, comparison with the past may show us in a poor light.

We must now consider an aspect of the technical advance of science can be called the "perpetuation of origins". This notion can best be explained by a few examples. In the late sixteenth century Copernicus undertook the task of revising the astronomy of Ptolemy in terms of an heliocentric universe, an astronomy then already some 1500 years old. Amidst all the changes that he made in shifting the unmoving centre of the solar system, he placed it, not at the sun, but at the *centre of the earth's orbit.* It was not until the keen mind of Kepler examined this work that this perpetuation of the old view was corrected. A more recent example is in the field of information theory. The formalisms of information theory bear very markedly the imprint of the domains for which the theory was first developed—exemplified by the telephone exchange. In generalising from the original formalisms in order to make other applications of the theory, much confusion has appeared in the meaning of terms. Present science is incapable of rendering the situation fully coherent. On the far wider scale, we can take the example of the notion of the luminiferous ether. Through the science of the Renaissance, the earlier notions of an underlying material substratum lacking in ordinary corporeal form* become identified with notions of "space". Later, Newton almost certainly conceived of a tenuous material occupying all space which had definite physical properties. Thus, the form of the original notion had been reversed, and the nineteenth century was left with the absurd legacy of an invisible omnipresent material which, though lacking in all ordinary physical properties, was assumed to provide certain mechanisms for "action-at-a-distance".**

* For example, Avecibron (eleventh century) distinguished between a matter capable of joining with the “form” of “corporeity “ to give bare existence. and a pre-existent substratum completely devoid of form. These ideas obviously developed out of the Aristotelian notions of Form and Matter, but these kind of notions were more widely spread than Greek civilisation. The *prakriti* of Hindu thought corresponds to the material substratum conceived of in the West.

** Even Maxwell wrote "... we are led to the conception of a complicated mechanism capable of a vast variety of motion . . . " " A Dynamical Theory of the Electromagnetic Field."

These examples may have made the notion of the "perpetuation of origins" clear. It is the action whereby certain components of past science are uncritically accepted because they are embedded in a complex of material. These components of a new piece of scientific work are so intricately involved with each other, that it is difficult to disentangle the specific formalisms and applications of the present moment of its arising from its more universal component. Finally, the notion of "perpetuation of origins" does not exclude the further notion that, in the course of perpetuation, radical changes and even reversals may have come about.

The argument we are putting forward is that the content of a present science always bears the traces of its origins. The course of development and change is reflected into the structural complexities of the present moment. *** This applies also to what we called the "membership" of present science, an aspect of which we shall be discussing later.

*** A simple example is the historical alternation of corpuscular and wave-like notions of light which reflects itself in the present moment of the wave-particle dualism.

Our argument is especially important for the solving of problems. From the start, it should be clear that problems are only what they are in a present moment of science. The problems of the nineteenth century about the ether are not our problems—if they were, they would be part of present science. If we say that the science of a particular moment "solved a problem" then we mean that in the science of later moments that problem will be no problem at all. On the other hand, the moment of solving a problem is also the moment in which the problem is made specific, for a solution also defines its question. Thus, the nature of the problem of the chemical elements could only be seen clearly after it had been solved. All this suggests that problems belong to a present moment of science — they are through and through historical.* We must add that it is problem together with solution that make the historical, not the problem alone.

* We are not excluding recurrent problematic themes such as the nature of atoms. The full character of historical science will be gradually developed in the succeeding arguments

These conclusions suggest that the notion of simple linear advance in time, with which we began this section, cannot be sustained. The present moment of science bears the imprint of the past course of events, il has an uncertain structural coherence of its own—contingent on the complexity of membership—and the "advances it makes over the past" are in reality an action within its own total structure. Against the common practice of measuring the components of the history of science in terms of the selective devices of contemporary science, we are suggesting that it is more realistic to recognize that it is the history of science which is the true measure of the science of the present moment. Only in this way can a general meaning be formed for the "advance of science".

The historical nature of theories

This is of special importance for the evaluation of scientific theories. Implicit in our argument has 'been the view that this evaluation is two fold. Firstly, there is the appraisal of theories that is "built-into", and "current" in a present science. This is a matter of the perception of its membership of scientists in the context of their own activity. Secondly, there is the evaluation which is based on a view of history. It is the latter which can concentrate on essential doctrines and make comparisons of a *Weltanschauung* relatively detached from the present moment of science. Naturally, present science is also a means of perceiving the past—as we suggested in the notion of the structural correspondence of present science with scientific development. We must state very clearly, however, that this structural correspondence is revealed in the act of doing history. It cannot be first inferred and then applied.

Though these two modes of evaluation often merge into each other they are opposing in intention; the first seeks for the clarification of the present moment, and the second for an understanding of the totality of present science—i.e. all moments of scientific activity.

In general, a later theory, one accepted by the community of scientists of that time, is assumed to be capable of showing the limitations of earlier theories. We have already discussed the inadequacy of the notion of linear advance. Revolutions, and break-throughs in science, e.g. from Cartesian to Newtonian mechanics and from Keplerian to Newtonian planetary theory if Descartes' physics is allowed no place in the "main stream" of science), are characterised by a change in the guiding notion of the nature of "correct science". Integral to this change is a re-orientation of science towards the natural world, manifested as a transition from one Weltenschauung to another.* The present moment of science is a *place of such transitions;* this is how it is able to act in the historical development of science. Hence there is no step along the lines of the previous theory, for the very structure of acceptable theory is bound up in transitions. This renders the notion of progressive- integration or inclusiveness in the progress of theoretical science ambiguous. Further, each new theoretical step is a discrete change of commitment which brings new heuristic possibilities. These possibilities render the theory vulnerable to future appraisals and criticism.**

* This is, of course, the picture of scientific revolutions so excellently presented by Kuhn in his *Structure of Scientific Revolutions.* We are, however, intro ducing an additional factor: the present moment of science as a scene of transition, rather than the change from past to future.

** C.f. the notion of Karl Popper that scientific theories are only falsifiable and never verifiable. The good theory is one which is easily falsified because it makes an unambiguous commitment whose consequences can he rigorously deduced and tested This is discussed below.

Consequently, every step in theory brings an essential uncertainty— it cannot be foreseen in what way the new theory will be found lacking because it will lead to many consequences depending on the context of application. Hence the simple notion of a step-wise progression of integration has to be radically modified. A case in point is that of Darwinian evolutionary theory which has many times been subject to qualifications such as the inheritance of acquired characteristics, and the possibility of major genetic "jumps", ideas foreign to Darwin's original conceptions.

The "Darwinian evolution" of to-day is not the same as that of the 1850's. We must always be wary of taking a theory as something thing-like, i.e. having a definite boundary and continuum of existence. A theory does not stand through the years. A theory is an accepted mode of thought about some phenomena which is operative within a present science; it is never timeless.

Metaphysics and scientific ideas

Often, it is upon the general consensus of opinion of scientists that histories of science lean in their appraisals of the past. There is established by science itself the sense of a chain of processes leading to the present state of science stretching back into the past. However, the further in the past one goes, the more difficult it is to find any obvious connection between the science and pre-science of that time, and the generally accepted views of present science. Attempts to interpret early ideas in the light of modern physics often show a great misunderstanding of the nature of these ideas. In the writings of S. Sambursky, a leading crystallographer, as well as a scholar of Greek and Stoic physics, there are many interpretations of early thinkers which are based on the assumption that modern physics expresses better what they were trying to say, than they themselves. In reality, they were at least as clear about their intentions as scientists are today — but their intentions were different from those of twentieth-century physicists.

Here it is necessary to distinguish between a set of metaphysical ideas and a modern scientific theory. Without going into problems of the demarcation of science, metaphysics and epistemology, we can say that such ideas possess an *unformalized structure* behind their overt form, whereas the modern theory is strictly bound to a formalized structure. It is the formalized structure of a theory that enables rigorous deductions -to be made, which can be tested against experiment.

This is not to suggest that experiment is in any way more "eternal" than theory. It, too, is subject to transformations. The formalized structure of the theory is inseparable from the conditions whereby it can be rigorously tested. Early metaphysical ideas do not have that kind of formal structure. They are ways of looking at the world each with its own potentiality as an aid to understanding the diverse manifold of subtle structures that make up the world. Any translation of these into something akin to a rigorously definable concept of modern physics results in confusion. There is, of course, an interesting attitude such as that of Santillana, who sees in early Greek thought the conceptual development which was one of the essential ingredients for the arising of modern science. The formal apparatus of experimental testing entered later. Burtt, in his classic *Metaphysical Foundations of Modern Science* goes even further in setting the religious and philosophical ideas of man of the seventeenth century as the foundation for the development of modern mathematical physics.

However, the more deeply one plunges into the history of ideas, relevant to science, the further does one stray from the path *actually taken* by science in its historical development. The *rigorous structure* of modern scientific thought, participating in the formalisms of mathematics, are quite the opposite to the general metaphysical ideas which evidently went into their making. Yet this is intrinsic in the nature of scientific thinking itself. Theories are never only rigorous—they are also vague, open to many interpretations, full of unseen possibilities, it is these hidden features that attract and fascinate. Each major theory- is like a work of art, created with its own unique structure of formula tions and root ideas. It may overtly be a theory of gravitation, yet it brings a re-evaluation of the status of space and time, changes in scientific methodology itself and even new aesthetic intuitions of the character of truth and beauty. Calculations alone cannot reveal these changes, for they have to be understood in the act of interpretation and re-interpretation—much in the same way as works of art challenge our usual ways of looking at the world, even when the overt subject of the painting or poem is the light falling on a chair in a bare room.

The prime feature that I want to emphasize here is the distinction that must be made between formal structures of thought with their definable properties and amenity to rigorous deduction; and metaphysical ideas which have a more ancient history and a power of penetrating into innumerable forms. The man who concentrates on one or a few basic metaphysical ideas — such as "atomism" — is a philosopher. The man who concentrates on developing rigorous structures using a blend of basic ideas as his conceptual tools is a scientist.*

* Certain points of this argument arose out of a Research Seminar conducted by ISERG in Easter, 1964. The responsibility for their interpretation here is of course my own, I am grateful to Mr. A, M. Hodgson for allowing me to use certain unpublished material from that seminar.

For brevity, I will refer to the powerful metaphysical notions which stand out in the history of ideas, as *recurrent notions.* These permeate the historical occasions of the formation of theories. With regard to these occasions—as in the case of modern scientific theories—that which can be rigorously described is complemented by what eludes such description. It is important we recognise that a narrowly defined and rigorous—or "factual"—investigation of past changes of theory may secure knowledge of a limited aspect of these changes, but it is liable to obscure any view of the total pattern. If only the formal changes are dealt with, then it is no longer a complete history. The world of history is made up of significant events, and changes robbed of their context have no significance other than that given them by our contemporary perspective.

Morphological relevance

Significance is given to the Arabic interest in practical experimentation because this is obviously aligned with the nature of modern science. Criticism is levelled at Robert Fludd and his alchemical notions because he opposed Kepler, one of the creative sources for the transformations of astronomy in the seventeenth century. This raises a very important question. What kind of significance in the history of ideas and operation in nature do events have which seem to play no role in the development of modern science? However broadly we define our criteria of relevance, there must always be an exclusion. This exclusion is of a different order to that of the rejection of inferior theories which we have already discussed, but it is nevertheless part of the same aspect of the situation. For example, the Ash'rite School of atomism played no significant part in the development of atomistic thinking in the beginning of modern science. Its very existence has been virtually unknown save to Arabic scholars, few of whom saw any relevance to the effective history of science. Is it, then, of no importance at all?

If it has any relevance to science it will not be that of a contributing cause, for there is no visible chain of transmission to the West. Yet, it played an important part in the total philosophic thought of Islam, and this thought did indeed have profound effects on the scientific activity of the West Beyond that, it is a manifestation of a *certain way of thinking* which has structural affinities with thinking very much alive in modern science. Roughly speaking, we can say that we are interested in two kinds of anterior science. There are the *morphological affinities to present* science and the *casual origins* of present science. The form of some of the ideas of the Ash'rite school is to be found in the science of today. Hence study of the school can develop our perception of the form in present scientific thinking. This approach is implicit in a great deal of the History of Ideas—such as the works of Jammer—but it is not wholly made of forms of thinking. Experiment, observation, and method in general are also relevant. For example, Anaxagoras has become perceived as the "first person to exemplify a rational science". Much is made of his "model" of the sun. In calling him this, we are saying that here is something morphologically akin to what we have today. Hence, defining the past reciprocates upon seeing the present. Morphological studies contribute to the image of present science.

The general theme of morphological studies is science as *a structural correspondence of thinking and action with the world.* Only in the casual n ow is it a unique nexus of interconnected events. The only basis upon which evaluations of the past can be made that are not a matter of measuring all ideas by the yardstick of the contingent and present state of science* is by taking morphological study *beyond the bounds of present science.*

* Rejection of the structural nature of science, and over-emphasis on the uniqueness of its historical content leads to an empty conventionalism such as that of O. Neurath who defined science as the nexus of propositions held to be true by people accepted as “scientists”. Implicit in his notions, however, is the notion of “present science”. One could almost say that the Encyclopaedia of Unified Science was an attempt to represent the present moment of science within the same moment which, in the limit, leads either to to the empty instant or to the structural coherence of historical science.

Our earlier discussions on the nature of theory led to the important distinction of formalized structures from recurrent notions and the interplay of attitudes towards the action of science. Correctness can apply only to the rigorous 'and formal structures of a theory which can he compared with experimental fact. Parallel with that formal side is interpretation, methodology and so on, where theory reflects the structures of thought, action and knowledge which make science possible, 'but which do not determine the actual content of science. Hence some kind of science may be inherent, morphologically speaking, in human culture, but its factual content is contingent.

It may be that at any particular phase of a science, out of the welter of ideas, knowledge and experiment there can only emerge one consequence (e.g. one accepted theory of gravitation). This single consequence will be representative of the nature of science in the sense of the structural correspondence discussed before. In ordinary language, it is truly scientific and correct. Yet it is never complete. Since theories have to be finite and discrete, their field of application is necessarily restricted. Even universal laws have *domains* in terms of scale and kind of abstraction. Their formalisms, essential though they are to scientific practice, are a restriction. The success of the theory means the diminution of the power of other ideas, which may contain material relevant and important to the field.

The axiological relevance of scientific thinking

However, ever since the inception of rigorous science, there has always been the conviction that science diverges from the occult or the mysterious, towards the rational and the demonstrable. At the very least, it is believed that it is a force acting against the influence of "strange" ideas about the universe and man, such as those professed by astrologers, or those inherent in the practice of unorthodox physicians or healers. It is that which affords certainty beyond personal belief, and hence, possesses an intrinsic authority by which to make judgements.

The struggle against the "dreadful superstitions that have darkened human minds"* is an important component of the image of the present science of the last few hundred years. It produces a criticism of the past that is not expressed in terms of mistakes or errors, but in terms of "irrationality" and "obscurantism". Nearly always, this criticism is also a moral judgement. The commitments and balance of forces within a present science are given value-interpretation that is concerned with the action of science in human life.

* Quoted from the preface in *The Autobiography of Science* edited by F. R. Moulton and J. J. Shriffes.

This line of evaluation is bound up with a two-fold conception of historical science. On the one hand it is treated as *inevitable,* as having to arise given the human mind and a certain degree, or kind, of social organization.* On the other hand it is treated as *precarious.* It is precarious because it is a recent invention that has to win its way against the irrational trends which dominate the minds of so many people. Science cannot be conducted automatically. It requires discipline and effort. Attachment to superstition and old dogmas does not. Therefore science could always be swallowed up by irrational forces. This view is most strongly brought home through the study of ancient science. We see the fantastic achievement of Egypt and Mesopotamia in science and engineering falling into decay under the pressures of politics and "religion" a thousand years before the birth of Christ.** The early astronomy of old Babylonia becomes enmeshed in the origins of astrology in the Seleucid period. The intellectual promise of the twelfth century in Europe becomes buried under the religious and political turmoil that rapidly took hold of the Christian West.

Yet the conflict of science and superstition is also seen in the very origins of science. Sarton, for example, speculating on the origins of the categories of number, says: "These numerical categories were the seeds of arithmetic, that is, of pure science, but also of number mysticism, or pure nonsense."***

He goes on to explain the combinational analysis inherent in the system of the I Ching, ending with a complete rejection of the "'Book of Changes" as damaging superstition. "Any scientific idea may 'be, and often is, perverted; that cannot be helped."****

* C.f. Benjamin Harrington's *Greek Science.* As a Marxist, he argues for the inevitable, though conditional, arising of modern science.

** C f Sarton . A *History of .Science Volume I* pp. 49-50.

*** Sarton loc. cit p. 11 **** loc cit. p. 12

Let us adopt a truly historical view here. How does Sarton know that the *I Ching* is nonsense? Is it not because such systems have no meaning in *the context of the action of present science?* Evidently the Book of Changes had a great deal of meaning in the present moment of ancient China. We will suggest that a judgment, such as that of Sarton, is an indication of *a component of present science* as well as a value interpretation of the past. The two sides are inseparable. Sarton's altitude which most historians would share—reveals the dominance in the present moment of a master-idea of "modem science" ; namely, that of a kind of explanation which excludes the non-causal, numerological and divinatory approach of the ancient Chinese. Such exclusions g ive us a clue to the natural boundaries of "periods" of science. Fundamental value-judgments on the past are an indication of the morphology of the present moment of science.

The relevance of "pseudo-science"

So far, we have discussed science against superstition and "modern" against "ancient" science. The notion of scientific advance always includes some idea that what is later must be better. In considering periods of regress, the time periods are adjusted so that there are worked out separate present-sciences in which advance is discernible. We have been arguing that this has the danger of involving the historian in projecting the morphology of his own present science on to the past. The greater the embrace of the past, the greater the possibility of discovering the meaning of scientific advance.

Let us consider recent science. Around the turn of the century, amidst the "progressive trends" commonly recognised by historians, there were two interesting components of the present science. The first was the curiosity widely current in the notion of the "fourth dimension" which spilled over into, and was also met by, a curiosity in spiritualism. Crookes was renowned for his investigation of para-normal phenomena, and on one occasion bore witness that his piano had moved of itself about his room. There were many other scientists—e.g. Oliver Lodge, Rayleigh, etc.—who joined in these investigations. Mach, in once writing about the fourth dimension, even felt obliged publicly to dissociate himself from spiritualistic notions.

Now the coupling of new ideas on space and time with what is now called ESP has not proved to be a passing phase of nonsense. The increasing literature which uses ESP phenomena as a starting point for a critique of the categories of space and time is sufficient evidence of this belonging—though admittedly in a weak sense—to present science. Here anticipations of the future enter into our judgments—if we believe this line of investigation is doomed to failure, it is dismissed from science altogether ; but if we admit that advances may be made along this line, then we can accept it into our present science. Accordingly, the spiritualistic fringes of the present science 1890-1915 become part of its morphology.

Another component was the development of hypnosis as an accept able medical technique. This may seem a curious statement, since nothing much was happening with the study or practice of hypnotism during this period. Up to the 1880's "mesmerism" had been following a chaotic career, ever since the time of Mesmer's original clinic (operating around 1780). By that time, Liebault, Charcot and Bernheim* were beginning to integrate hypnotic procedures into their current practices in dealing with neurotic disorders, and also finding—though with great difficulty—a new formulation of the hypnotic process, which did not involve the embarrassing notion of "animal magnetism". Much later, hypnotism was to become an accepted technique of medical practice and experimental psychology. The present moment of science at the turn of the century was a scene of consolidation. Compresent was the influence of the new psychology—the emergence of psychoanalysis in the impact of Freud, and the 'build-up of experimental psychology from the work of Wundt, Fechner and Lange. The violent history of the "mesmerist cause" went into oblivion, leaving a certain technique, endowed with the new and vague conception of "suggestion", slowly to percolate into medical and psychological practice.

* He published *De la Suggestion* in 1884

Thus, in this period, we can discern a segment of the total transition from mesmerism to hypnotism which reflects the morphology of the science of that present moment. The significant point is that this transition can be interpreted either as a selection of what is correct about mesmerism, or as a reflection of the limited capacity of the science of that time to incorporate certain elements of Mesmer's original practice. This uncertainty can be agreed to only if we, as historians, evaluate our present understanding of hypnotism critically. We would all agree that what was once a matter of violent controversy, and astonishing phenomena, has become to-day a matter of routine and the classified phenomena of "suggestibility". It is, however, a matter of choice whether to sec this purely as an advance, or as both a gain and a loss to science.

As we converge to the smallest components of a present science, the conceptions of our contemporary science become more and more needed if we are to order and classify the facts. If, for example, we make a study of all Lavoisier's writings then we can only order them according to their explicit scientific notions. For this, we have to use our knowledge of modern chemistry. If we enlarge our embrace, how ever, the conceptions of our present science themselves become called into question. The history of science is littered with hastily skipped over anomalies – ones which science was compelled to bypass because it did not have the morphology capable of appropriating them into useful action.

Spontaneity as a factor in scientific advance

There is, evidently, a fortuitous element in the selection of material with which, at any given moment, present science is able to cope. We must not underrate the importance of this element in our attempts to exhibit science as a purposive and conscious advance from the unknown to the known. Somehow, we believe, people distinguished out of the complex nexus of thought, perception and patterns of action, the technique of using mental images connected to formalised structures (such as mathematics) that could he operated on and matched with perceptual evidence.

This particular "game" became interesting — and when it entered into the transmission of patterns of action, it produced amazing results. We have used the word "game" deliberately in order to emphasize the spontaneous or non-casual element in the advance of science. Practical needs certainly played a part, but ideas that the Mayas or Babylonians built their vast observatories or Ziggurats for the sake of making an accurate calendar, or that geometry began because the Egyptians had to remeasure the farmers' fields after the flooding of the Nile, are no longer tenable. Science became interesting for all sorts of reasons : as a philosophic discipline for Plato and his pupil Eudoxus (who produced a spherical model of the solar system as an exercise in making plausible explanations); as a means of clarifying the problems of transubstantiation for mediaeval intellectuals (who enquired into the laws of motion partially in order to understand the meaning of the presence of the Lord in the Sacraments) ; as a way of achieving better health through the discovery of the laws governing the body for Descartes, himself of poor physique ; as a means of worshipping God through revelation of His works for Kepler and Newton ; as a vehicle for expressing the spiritual nature of the world for Goethe; as a support of atheism for Maupertuis; and as a means of gaining destructive power by modern governments, to cite but a few of the motivations observable throughout the history of science.

The subordination of science as a *means* enables it to participate in the larger present moments of historical occasions. At the same time, it is practised as a *good* in itself, and lives its own independent life. The notion of an *essential* science is also relevant to our theme. It is this which is at the heart of the conflict between ancient and modern science, or between science and superstition; and which is the centre of the ambiguity of the rigorous and at the same time obscure nature of scientific ideas.

One of its expressions is the conflict between experiment and experience. Experimentation is a way of obtaining knowledge of the world which must, inevitably, become standardized and selective. Experience, on the other hand, is to be measured in terms of one's degree of perception, and does not exclude any kind of knowledge. The way of experimentation allows the exchange of acquired knowledge so that all can use it if they so wish. The exclusion of extraneous variations yields the knowledge of atomic components. The way of experience, on the other hand, yields a variety of knowledge which can be exchanged only according to the degree of perception of the people involved. It deals in totalities, and the given organization of experience. Experimentation has to be supplemented by theoretical constructs which supply the "hidden mechanisms" which serve to connect the atomized com ponents which it furnishes.

The polemic of Goethe against Newton was based on this duality. No matter how correct Newton's theories are for the results of his experiments, these experiments themselves exclude significant structures of our experience. If this is forgotten, then we have no real understanding of colour. But the "phenomenalism" of Goethe was based on Goethe's perception, whereas any schoolboy can repeat the experiments of Newton. Goethe's simple and beautiful experiments can, of course, be easily repeated. But it is another matter to have that synthetic insight which was the property of Goethe's mind. That kind of perception is intrinsic to the *meaning* of the experiments. Schiller, for example, could not accept that Goethe saw the *Urpftanze.* For Schiller an "idea" was *mental,* and not part of the *world.* For Goethe, the ideal forms of things were discernible in our experience of them. Can we allow that one man can see what others cannot? This question only arises when science occupies a particular present moment for which reproducibility and verifiability are universally accepted as criteria of "correctness". These criteria characterise the present phase of experimental science with its tendency to concentrate exclusively on a limited region of possible structures and experiential content. To "practise science" is to become interested in exploring one such limited region. But this does not remove the fundamental opposition between experimental science and the total engagement of man in a universe of infinitely complex structures and powers.* There are to-day, signs that we are ready to accept the possibilities of pragmatic limits to the reach of science because of the limitations of our powers and our very consciousness.**

* C.f. for example Schrodinger "The Spirit of Science" in *Spirit and Nature* (papers from the Eranos Yearbooks) "... all knowledge relates to the spirit, or more properly, exists in it, and this is the sole reason for our interest in any field of knowledge whatsoever. The knowledge ... of this circumstance is indeed as old as the urge for knowledge itself. . . The sudden and spectacular progress of natural science deluded some of its most brilliant exponents into supposing that science was about to throw light on everything that was worth knowing, that outside of science nothing of the slightest interest would remain. . . "

** C.f. Pierre Auger, *New Scientist,* 24th September, 1964 ' Limits to Science'. . .the question may be asked whether there is not an outward limit to the range of abstraction and complexity which can be covered by human thought and in particular, mathematical thought."

The historical tensions we have studied are the key to understanding the changing morphology of science in history. The demarcation of science as an independent life is discernible through the tensions and ambiguities of present moments of science, as well as through their quotas of widely avowed successes.

3 THE MAKING OF SCIENCE

Once we go beyond the boundary of the contingent facts of a present science, we have to face uncertainties of meaning. These do not stem only from the nature of our powers of interpretation, but are present in the morphology of that present moment of science. They are not a deficiency, but an essential attribute of anything that could be science. Attempts to separate off a portion of the content of scientific history as the "genuinely" scientific component stem from a misunderstanding of the way in which science is structured.

A present science is a moment of change. This is a necessary feature of its involvement in past and future. Within that moment, contributions are being made to the advance of science. In historical interpretation, the evaluation of these contributions involves a greater embrace than that of the perception of the scientific community of that moment. It reaches further in duration and more broadly in membership.

The contribution to the advance of science must obviously arise out of the legacy of the past and be evaluated in terms of the future. However, the work of the historian is in discovering the action of the present moment which makes tnat moment an historical reality. Science is not simply a continuum of activity—for this would allow no real advance or progress. There is a morphological differentiation that allows for an action in the present moment which transforms the legacy of the past and realizes the future. This action takes science out of the realm of mere happenings and brings it into the dynamics of history.

At the same time, we must allow that the legacy of the past is also an historical component of science. It is transmitted from the past as the traces of previous moments of science, but is also shaped, selected, and re-formed by the present moment. Of equal importance is the anticipation of the future in the present science, which shaped the aims and progress of that time. The historian must also engage in a *reciprocal* evaluation of the present moment and future moments of science. For in that region are to be found the most difficult questions: how does man foresee and interpret the future? Why do the aims of the present moment so often fail to be realized? How is it that certain men in their actions almost literally seem to belong to the future?

A present science is not made by the momentum of the past. Periods of stagnation do not belong to the history of science. A present science is dynamic, and its dynamism enables it to live on in the history of science. This dynamism is both within and outside of the present moment. The significant action of a present science indicates the morphology of the relevant dynamism. By this morphology, the present moment "interlocks" into itself so that it remains coherent in the whole nexus of scientific advance. There are, of course, subsidiary dynamisms which relate a present science to its historical context and these can often help to illuminate the structure of action within science itself.

The attention of the historian is directed to the compresence of a nexus of actions. He has to discern a morphology of the actions of a present science, which takes account of past and future, and the 'historical environment" of the morphology of the total present moment of the period. It is the compresence of scientific action which is the historical reality of science. This is not an "eternal" component of science: nevertheless, considerations of their results in the stream of present moments alone cannot afford an adequate treatment. They are historical realizations which remain in the present moment of their actuality.

In order to clarify these general notions, we will discuss the three main kinds of component which constitute the dynamism of historical science. These are: the legacy of the past, anticipations of the future, and the action within the present moment. Each of these demands an independent investigation while remaining interpretable only in terms of their integral structure in a present science.

(a) ***The Legacy of the Past***

The investigation of the transmission of knowledge and techniques is one of the major tasks of the historian of science. It can extend back into pre-history. The diffusion of knowledge of cereal-production in the Neolithic age is a prime example of the slow growth of a community of traditional practice. Local differences were mostly contingent on geographical factors. By about 4,000 B.C., Egypt, Europe and the Near East shared a common knowledge of food-grains, and even of how to breed and domesticate cattle.* This general homogeneity of technical knowledge was attained only after a complex development some 10,000 years ago of relatively independent cultures in Europe, the Near East, the Far East, and Central Africa. The bringing together of the diverse inventions of language, ritual, art, methods of cooking, husbandry and so on seems to have been centred on the Mesopotamia region, and extended into North Africa, Persia, Afghanistan, and Eastern Europe. The morphology of these astounding developments remains obscure—but we should remember that it was part of the great historical moment of the creation of modern civilisation. Their legacy was a body of generally shared technical knowledge, amidst which we can discern special agents of transmission. A new kind of hetereogeneity soon arose. Smelting, and later, writing, proximated the time of the rise o f certain civilisations, especially those of Egypt and Sumeria, which were well established by the third millennium B.C. With these developments, the specialization of cultures increased. Techniques became geographically separated, and transmission more a matter of commerce as we know it in modern times.**

* C.f. Gordon Childe “The Prehistory of Science " printed in the anthology, *The Evolution of Science* (Mentor 1964)

** C.f. Leonard Wolley *The Beginnings of Civilisation, History of Mankind II*

By about the first millennium, there had arisen specialised branches of knowledge and practice, approximating to our present specializations though far less diversified, such as medicine, agriculture, arithmetic and astronomy. The transmission of knowledge and techniques then became more hazardous, for the proper use of them depended on the support of a suitable context. The lunar calendar of the Babylonians, which employed as a unit of time one-thirtieth of a mean synodic month, was transmitted to Greece, and from there to India in the vehicle of Hellenistic astrology (second century B.C.) The context of Indian astrology was totally different from the Babylonian source of the techniques and applied to different problems. In fact, the Indians took their unit of time as one-thirtieth of the actual lunar month — a complexly varying quantity.*

On the positive side, we should remember the immense value of observational Babylonian astronomical data to Greek astronomy. It was through this data that the Greeks were able to review the movements of the planets, moon, and sun over many centuries in order to assess the plausibility of their explanatory models of the universe (or solar system).**

Leaping forward to one of the most remarkable phases in the history of the transmission of knowledge, the early Middle Ages was the time when numerous translations of Greek and Arabic sources were introduced into the West, arousing it from its slumber of intellectual isolation.*** This well-known episode of Western thought in general, and the history of science in particular, reveals much about the nature of science. In becoming conscious again of the knowledge of past genera tions (leaving aside questions of the interplay of ideas and changing social structures) one of the essential foundations of science was regained. Science essentially involves the accumulation of knowledge and techniques. The rediscovery of Galen, Archimedes and Ptolemy made a link with the past so that a new work could begin. The ordering of rediscovered knowledge and the practice and elaboration of techniques were the precursors of later criticism and technical development.****

* C.f. O. Neugebauer "Survival of Babylonian Methods." *Proc. Amer. Phil. Soc. Vol. 107,* number 6.

** C.f. Neugebauer *loc. cit.* p. 534

*** See, for example, Weisheipl *The Development of Physical Theory in the Middle Ages* and A. C. Crombie's table I in *Augustine to Galileo* Vol 1. for a comprehensive list of translations.

**** C.f. Clagett *Science of Mechanics in the Middle Ages.* "While the solutions of these problems (involving the causal and descriptive aspects of equilibrium and of " natural " and " forced " motion). . . lie ait least in a general way within the basic framework of Aristotle's natural philosophy, still these solutions reveal important aspects of the medieval logic and descriptive analysis that were to prove useful in early modern times when the Aristotelian framework has abandoned."

This points towards another important feature of science. Knowledge is only effectively present in science if it is participating in the actual work of the time. For example, Vitruvius, in the first century AD made a series of investigations into the acoustical properties of amphitheatres. It was not until the late nineteenth century that Sabine, himself engaged on investigating the acoustics of a lecture theatre, brought the work of Vitruvius into science again.*

* I am indebted to Mr. Fred Wheeler for bringing this example to my notice. Vitruvius' work “De Architectum" was known in the 12th century but remained dormant until the acoustical investigations of Sabine.

In general, one could say that knowledge and techniques are like the "physical body" of science. They constitute its most stable coni- |x>nent. But even they have a hazardous existence, being dependent on the interests of science that change from period to period, or even from branch to branch, or person to person. Such considerations are especially pertinent today when accumulated knowledge, by its quantity alone, has rendered itself mostly inaccessible to any individual, group, or even to the whole scientific community.

The history of the commerce of knowledge and techniques is a way of charting the path of science. At the beginnings of urban civilisation this commerce reveals the differences between different, cultural centres Babylon, Greece, India, China and Egypt. Just as the Babylonians exchanged smelted and cast metals for raw ores with their Northern neighbours, the Hittites, so the practical techniques and knowledge of Babylonian astronomy were transmitted to Greece, and from Greece later came the "refined" products of intellectual explanatory models. Obviously, the roles of cultural centres were changing. There is little doubt that in the period from about 800-500 BC., many Greek thinkers imbibed directly or indirectly, ideas from Babylonian sources. By the time of Plato, however, it was Greece who represented the ideas-source for the Near East, though there was evidently much exchange with India.*

* This was also true for techniques of self-transformation. The influence of Buddhist methods on the spirituality of Greece and the reigns of the Eastern Mediterranean is also well attested.

Every present science has its own way of standardising the trans mission of scientific material. As we have seen, this involves representing the past in terms of the content of the present activity of science. In modern science, the text-book builds up a picture of a continuous transmission from the "great moment" of the arising of modern science to the present day. Yet the legacy of the past is not a continuity of existence extending from the past into the present. The sense of continuity arises from the mechanism of standardised transmission—e.g. the forms of education. It is not true to the action of science. What is historically significant is what is available to present science, and its image of how *it stands* at that moment. This image is its "perceived past".

In this way, we see that the legacy of the past provides essential material, or *points of departure* for present science. At the same time, it *conditions* what is possible and causally leads to problems in that present moment of science which tries to advance beyond it. It is important to explain more clearly this causal aspect of the legacy of the past. What comes from the past is not simply inert—it carries with it a momentum, and upon this momentum the general activity of the present moment of science depends. This momentum exerts a *causal pressure* on the present moment which is commonly interpreted as a *legacy of problems.* Associated with this, of course, is the notion of causal continuity to which we have already referred.

The "problem of motion" exemplifies this legacy of problems. In Islam, the focus of dispute was around the Aristotelian and Platonic concepts about the imparting of motion from one body to another. Both involved a theoretical mechanism whereby the air through which a projectile moved was the instrument of its motion. Both had deficiencies with respect to the observed phenomena. Yet the formation of a theory enabled criticism to follow, and hence the emergence of a clearer and wider conception. This was the task carried on in Medieval Europe during the period of decline of Islamic science.

One significant feature of this transmission of a dispute on motion was the disappearance from the scene of many interesting lines of thought. As an illustration, we can take Stoic thought. In the writings of Chrysippus (282-209 BC.), there is a reference to a notion of a *tonike kinesis,* or a "tensional motion". This was associated with the notion of pneuma, the active "breath" which permeates the material substratum and produces organised structures.* Pneuma, within matter, is the source of "tensional motion" which produces organisations, their relations, and their processes. In this view—though it is difficult to justify this interpretation unambiguously from the texts—the imparting of motion is but a subsidiary component of an over-all complexity of hidden motion. Further, Chrysippus came to the notion of infinitesimals, and almost to the notion of differentials. This was a component of his general physical view. For example, his answer to Zeno's paradox concerning the "unmoving arrow" lay in the notion of present duration: "part of the present is in the past and part of the future". The "now" can only be "defined broadly".**

* Galen's Aristotelian interpretation, that *Pneuma* was “the form of the primordial matter" was probably misleading since there were significant differences between the Aristotelian emphasis on *entities,* and the Stoic emphasis on process.

** Quotations from Galen and Chrysippus taken from Sambursky's *Physics of the Stoics*

It is fairly clear that here we have an organic system of nature rather than a mechanical one—in the sense of the monadology of Leibniz and the philosophy of Whitehead. This mode of thought was really not to come into prominence again until this century. In Chrysippus' notion of the preliminary and determining causes relevant to an organization we have the germ of the notion of a "system" such as in General Systems theory.

(b) Programmes for Advancement

Our ordinary assumption that science is here to stay is as weakly founded as our belief in the stability of our present social orders. Traditional India, for example, had no real heart for science. Modem historians confuse the interplay of recurrent notions embodied in the ancient texts of the Vedas and the convergence; towards rigorous science. But there was not, in Early India, that special force which is essential to scientific advance. As far as one can ever generalise about a people, the Indian concern was always with the Eternal Being and the certainties of cosmic cycles, and never with contingent fact and temporal process.* In the scientific sphere, this resulted in a concern with *logic* rather than with empirical investigation.

* We should allow for their insight into medicine. Examinations were always thorough, and they had a clear logical system of concepts. Methodology, however, lagged far behind. It is interesting to note that Indian physicians were probably a great influence on Hippocrates and early Greek medicine in general. There are traces of Indian sages visiting Greece at the time of Socrates also.

Undoubtedly, the notion of the Eternal has played a part in science we have only to remember Parmenides and the philosophic upheavals of Greek thought. More importantly, it is inherent in our nature that we feel an attraction towards conditions beyond the destruction of time, and a perfection of self organisation that can never be disturbed. This is the "mystical" side of scientists in their effort to grasp world-order, immutable laws, or reach finality.

The force of concrete science is, however, missing in many cultures. Byzantium had no interest in analysing the recurrent features of the the phenomenal world, being more concerned with the synthetic actions of art, the conceptual world of theology, and the exploration of the possibilities of the cultural world of antiquity. The force of nature itself was of little interest. After all, it was not until the 14th century or so in Europe that even painters thought the natural world of sufficient interest to merit their attention.

The mediocrity of Byzantine science—consisting mostly of a rehash of Greek material—is often regarded as a result of its being subordinated to the Church and immersed in the legacy of Greece (and Persia). Yet it is significant that the Church was in conflict with the Neoplatonic tradition.*

* Justinian closed the Athenian School in 529. The authorities were constantly rejecting influences from the past legacy of Greek thought enforcing a Christianisation of all branches of life. Countless scholars, fled to the great schools at Jundishapur (6th to 8th centuries) and Baghdad (from the 8th century) where thinkers gathered from India, Greece, Syria and Persia as well as Byzantium.

The Church was the *guardian of the future*** and was conscious of a need to become free of the pressures of the past. Its intellectual energies were in the early centuries absorbed in the creation of a theology—some thing necessary for the new social organisation of the church. Part of its 'mission manifested as expansion and conquest on the one hand, and practical charity on the other. The first exploited the devices of Hero of Alexander in machines of war, and the second produced an astonishing number of hospitals and places of care. Science was of little use in these immediate tasks, and was most unproductive in comparison to art. Hence the study of arithmetic, geometry and musical theory were brought as a part of the quadrivium, only as a mental training.

** C.f. Meyendorff *A Study of Gregory Palamas* "the eschatological *future* stands for an *already present reality,* fully anticipated in the Church. . ." p. 185

When we place ourselves in the Byzantine empire, it is difficult to grasp how anyone could have anticipated the effect which science was eventually to have on human life. In such a period, science is not seen as an advance, an action of progress. The progressive action, was the Christianisation of the World — and war, art and theology were its interests,***

*** Also, the writing of history — an important action for a culture which is shaping itself

The force of modern science is bound up with technology. If we become more aware of the significance of developments in social organisation, the power of technology in our lives will soon diminish, and science have a different standing. We can discern, in the thought of Islam—which deeply influenced the emergence of science in the West— an anticipation of man's increasing power in the natural world*. As the Quran says: "O company of Djinn and Man, if you can overpass the bounds of the Heaven and the Earth, then overpass them. But by *power* alone shall ye overpass them". "Power" was seen as a means of getting beyond the phenomenal world. Islamic philosophers invited man to consider the possibility of piercing the veil of nature by a frontal attack. Needless, to say, this is a far cry from modern machinery. Nevertheless, the discovery of vast resources of energy in recent times has done much to tear aside older representations of the natural world and man's place in it. The point is that our present condition is a peculiar vindication of the prophetic urges of the science of Islam — a science of act and energy.**

* Some valuable material on this theme is to be found in Iqbal *The Reconstruction of Religious thought in Islam.* The author, however, mingles together two different aspects of Islamic science and philosophy. One is the *causal pressure* exerted in the west, and the other is the anticipation of the future which *exerted a pull* on the thought of Islam.

** *Loc. cit* "Every atom of Divine energy, however low in the scale of existence, is an ego but there are degrees in the expression of egohood.' Such was the doctrine of the Ash'rite school.

The speculations and urges of a present science are also dreams and images of the future — some remarkably apt. Sometimes they are anticipations of a future which the present moment of science itself will help to create. Needless to say, these anticipations are experienced as an urge towards the future, and are often seen as a direction operating from the present moment. Thus men advocate lines of research and direct activities in the belief that they are determining the content of the future.

The influence of man and groups may rise in the field of ideas, method, organisation or lines of research. Whereas men serve to transmit the legacy of the past by teaching and translation, they influence the organisation of science by orientating its endeavours. The synthetic endeavours of Aristotle, commented on and systematised in the philosophic work of Aquinas orientated Western science for many centuries. It was not of course the only influence, as is evident from the interest of people like Roger Bacon in practical experience as against speculation. Bacon certainly had dreams of the future in his anticipation of mechanised flight, submarines and so on, and his alchemical vision of transmutation.

The life of an organisation of scientific material, blending recurrent notions and having the power to find expression in a style of science, or even in a phase of development, appears as a series of concentrations of force emanating from men at different times. It is often difficult to disentangle the influence of different men which may be concentrated together in an individual. The usual result of analysis is an incomprehensible assembly of forces, whereas the important fact is their integration in terms of the future yet to come.

A crucial feature of this power of men and groups to organize the working out of science is its concurrence with a *programme for advancement.* Endless examples could be cited. One of the most important is in Newton, who is developing his physics interpreted his method as a way of conducting science that could lead to definite, as against spurious, progress.

"To tell us that every species of things is endowed with a specific occult quality *by* which it acts and produces manifest effects, is to tell us nothing; but to derive two or three general principles of motion from phenomena, and afterwards to tell us how the properties and actions of all corporeal things follow from these manifest principles, would be a very great step in philosophy, though the causes of these principles were not yet discovered. And, therefore, I scruple not to propose the principles of motion above mentioned, they being of very general extent, and leave their causes to be found out".

Classical science is almost equivalent to "science in the style of Newton". As Descartes' style of science was spread by the informal scientific society operated through Father Mersenne, so the way of Newton spread, after an initial period of difficulty, by way of the Royal Society.

The argument we wish to put forward is that it is the future which makes a certain demand on the present moment. We would agree that a man can see "the way in which things are going" and from this be led to action in the present. This was the experience of Newton who saw the 'old ways of science' getting nowhere, and only leading to confusion. He, like Descartes and Bacon, advocated a direction of endeavour in order to diverge from the way in which science seemed to be automatically tending. This was manifested, in part, as a reaction against the past. But then we have to ask the question: Why should they have become dissatisfied with the way in which things were going? We have to remember that they were not really lonely figures fighting the inertia of a whole society almost single-handed. They were representative of the period. Also, men only became discontented with how things are if they are aware of the possibility of things being different. All round Newton, Bacon and Descartes a new world was shaping, with new conceptions of man and the universe. Most important of all, there arose the sense of *urgency.* This precipitated and heightened the crisis in science — emerging as it was out of a welter of influences, intermingled with astrology and alchemy, partly constituted out of commercial techniques, and sadly lacking in any coherent organisation of knowledge and methodology.*

* The philosophy of Locke, Hume, Berkley and Kant can be seen as an attempt to "catch-up" with the future of the science of the seventeenth century, when generalised methodology began to emerge.

Something was needed by the future and men were aware of this. Historically, we can treat the future as already there; not a predeter mined future, but a future of patterns of events for which the present moment of seventeenth century science was a preparation and a region of free creative action. Men were aware of the future in two ways: intuitively and by way of current ideas. The former gave them the sense of urgency, and the latter images of where to look and what to set about. Of course, the programme of advance was coloured by the content of the present moment and the particular experiences of the won concerned. These ideas are not really strange if we consider the common experience of the research scientist that he recognises what *will be* fruitful to investigate before he knows that in fact it is.

Evidently, the demand of the future is not causal, neither is it gratuitous. Hence the clue to the future is in the pattern of urges within the present moment of science which are distinct from the causal pressures of the past. This demand, obviously, must relate science to so ciety and hence the future can often be discerned in a change of attitude to this relation. In the seventeenth century, Bacon's "New Atlantis" was a phantasy, but in terms of times to come, it remains a real insight into the pattern of the future, in spite of the — to our eyes — ludicrous picture of scientific method. It is through the future that a present moment enters the movements of history.

The question can be asked: if the future can truly be anticipated, are there then examples of scientists working in terms of a science not vet present? There are many such cases. Here we can consider as an illustration the work of Leeuwenhoek. This isolated Dutchman, applying himself to the microscope in the late seventeenth, and early eighteenth centuries produced an astonishing series of observations. No one else at that time saw some of the things that he saw. For example, he recognised and drew bacteria, organisms not to be encountered again in biology until some fifty years later. Such spasmodic occurrences serve to support our contention that we should consider the general present moment of science as our historical unit rather than the aggregation of the work of its members. A present science, as we have already said, has an inner dynamism which enables it to hold its own and have a place in total history.*

* We are not suggesting that this vitiates the lives of scientists. These, too, have a dynamism which gives them a place in the life of a present science.

c) The Structure of Scientific Action

Consideration of the making of science leads us, finally, to the action in the present moment that links together the future and the past. Within the present moment itself there is the structure of action which, as a whole, makes progress. We must examine how we are able to interpret the actions of the past in order to find this structure.

A statue within our present moment can inform us of the tools used in its execution if we carefully examine its surface and have knowledge of the art of sculpture. It is another matter to discern the purpose of the statue, created, let us say, four thousand years ago in a civilisation we can scarcely picture to ourselves. In general, the activity of the past leaves ambiguous traces. There is an invisible and a visible component. The great pyramid is the expression of a creative ideal as well as a device of entombment. Creative and utilitarian purposes have entered into the same complexity of traces.

Every present science leaves traces of a complex activity for which we have to infer a structure. This structure enables us to say what was going on at the time, and how it was organised. We have to invoke our experience of the present moment of science in order to come to some understanding of the structure of past activity. We have to be aware of the pressures incumbent on science in our time for these enable us to interpret traces of the functional role of science in human society. Further, we have to grasp the organisation of scientific practice today, for only in this way can we appreciate the requirements of coherent operation, Again, we have to be aware of the purposes which scientists entertain in their work, for this is our only clue to understanding the intentions of the past which have left their legacy of complex actions and ideas.

Newton, through the magnificent work expressed in the *Principia* and the *Optics*, introduced into science a whole complex of methods. As science progressed, these methods become absorbed into the structure of scientific activities, but the intention of Newton's thought—'towards a style of reasoning, and towards worship through the study of Nature — fell away. In general, it appears that the aims of individuals leave a trace in present science as a residium of methods. The "content" behind the formalisms and methods plays no obvious part.

However, our discussions in section 2 about the ambiguous nature of science should caution us not to deny these qualitative, directional factors an integral part of the progress of science. At the same time, we should not exclude the directedness which stems from outside the bonds of recognised science. Intentions from any sphere of human experience can be transferred into the present structure of scientific action.

Within a present moment of science we can discern four sources of the total activity, differing in character. There is that component concerned with practical results. This leaves traces in the form of the results themselves—instruments, maps, tables, etc. Secondly, there is the component concerned with *ways* of getting results, utilitarian or otherwise. Its main traces are in the 'history of organisations', discernible through archives and sometimes preserved in organisations of the present moment, and in the legacy of scientific practice operating at later stages of the scientific activity -again, this is discernible from documents ami also *traditions.* Thirdly, there is the component of the purposes of those who influence the course of science. Within the present moment itself, much of this remains hidden—"behind the scenes" as it were. Documentation is hardly adequate—without much "reading between the lines"— as a trace of this third component. Indeed, one can say that it leaves very few direct traces at all. People do not in ordinary life explicitly record their intentions. In science, men have been groping in the dark, and we should recognise that their seemingly precise and rational accounts of their aims and purposes are only the surface of a deeper substratum of intentions.*

* This view does not commit us to a “psychoanalytic” interpretation of science. Nevertheless such an interpretation is relevant to the point we are trying to make.

Finally, there is the component which is concerned with the creative transformation of man and society—an invisible component in any present: science, though variously reflected by different members of scientific communities. One of its most important reflections is in the concern of individuals with the nature of *mind.* Another is in notions of human destiny. At best, this component leaves traces at third hand— in the expressions of individuals and the actions of organisations. The historian—as we have suggested before in our discussion of the meaning t»f scientific advance—has to make his own choice on whether to accept the historical reality of this "invisible" component. On it hinges the whole meaning of science as an instrument for human evolution. It is a pattern for realisation in the present moment, though it presents itself to individuals in terms of the temporal future through conceptual images. At the present time, the problem of human progress and the relevance of science to this progress, is of present concern.*

* Margaret Mead *Continuities in Cultural Evolution* and my review discussion in *Systematics* v. 2 no. 4

Our present uncertainty concerning the nature and reality of human is reflected in our uncertainty concerning the source of the creative transformations of the past.

It is the region between methodology and purposes that constitutes the *field of action* of science itself. The substratum of this field is its results. We also posit a creative source operating through the human mind.

Let us pause and consider the features of this field of action a little carefully. Methods are, of course, ways of working, instruments for producing effective results. Their evolution is essential for the progress of science. It is not a gradual evolution. Anomalous discontinuities, and sudden jumps, are to be found throughout the history of science, and cannot be easily explained purely in terms of a science constituted only of such methods. There are limits to the "natural growth of methods".* For 1,000 years Ptolemaic astronomy was virtually stagnant as the only method of astronomy. It was itself based on geometrical suggestions made by Hipparchus, and intimately bound up with the contemporary Greek approach expressed by Geminus in the 1st century A.D.

"Sometimes he (i.e. the Astronomer) does not even desire to ascertain the cause, as when he discourses about an eclipse; at other times he invents by way of hypothesis, and states certain expedients by the assumption of which the phenomena will be saved".

* Neugebauer *The Exact Sciences in Antiquity. ". . .* the absence of algebraic notations should not have prevented the Greek geometers from developing what was called in the 19th century "synthetic" or " protective " geometry since many of the basic concepts were ready at hand in the works of Apollonius, Again, such a natural development did not take place ."

Astronomy was treated purely as a method of calculation. It used a geometrical model of the solar system based on circles moving on circles, since circular motion was thought to be inherent in celestial revolutions. But it did not seek out the *physical causes* of the phenomena with which it dealt. Even in the 16th and 17th centuries, we can see signs of the same .attitude: Osiander's famous preface to the "De Revolutionitus" of Copernicus presented it only as a method for "saving the phenomena"; on the other hand, the Cartesians accused Newton of not doing real physics because his theories were based on geometry.

This separation of expedient methods from truly physical reasoning suggested by Geminus offers us a valuable due. There is certainly an element of belief or commitment in science that cannot be legitimately abstracted if we want to understand the history of science.* Every scientist, in advancing his work, is called upon to make a commitment in terms of the science present for him. Without some kind of commitment, he cannot act. In standardised procedure “commitment” is inseparable from action. Where it is separable, the act of commitment can become the agent of the transformation of the character of present science. Later, we shall have to allow for the relativity and structure of the present moment of science determined by the individuals and actions which compose it, for this is the basis of the self transformation of science. Commitment can be regarded as a purpose entering the present moment of science. This gives the intended meaning of the scientific situation. The crucial point is that this meaning is inseparable from the present moment of the scientist himself, who cannot be totally aware of the present moment that is in process of being fashioned. This allows creativity to enter as the *spontaneous* element.

** Cf Michael Polanyi, *Personal Knowledge*

A recurrent commitment is a *belief. A* belief about the nature of the world of fact, or science, is not dependent on corresponding methods, though it will direct their use and encourage or suppress their invention. A belief about the world and science can shape and direct a body of techniques. When a belief has an effective method to correspond with ii. then the belief becomes an assumption, and plays no creative part in the progress of science. It is only when belief and method are sffil distinct that creative steps can be made, and, in general their interplay is the condition for a vigorous field of action.

We must say more about the side of belief, for it is here that science merges with, or is likened to, the directedness in other fields of activity. Beliefs about the world or science are inseparable from an action involving the transference of experience of one domain into another. In making a model for a set of phenomena, the physical properties belonging to one situation are transferred into another—a common heuristic device. Take for example, the planetary model for electrons postulated by Rutherford and Bohr. The spatial configuration of the solar system—a central sun about which revolved the planets-— was applied to the atom, treating the nucleus as a sun, and the electrons sis planets moving about that sun. It should be noted that analogical reasoning is common to all forms of thinking and is by no means confined to science. In our own time, however, analogical reasoning has come to the fore. One of its important features is the allowance made for relativity and its concern with structure rather than with appearances.

Much more is involved than making analogies. However, the example does exemplify one very important feature of this element of belief. It involves a transfer of the structure of one situation to another. These are taken usually to be conceptual, but in fact, they may also be intuitive or passionate.

If we say that method is the way in which the scientist interacts with the world apart from himself, then, belief can be interpreted as how he sees the world *of which he is a part.* It is no accident that changes in the direction of science are correlative with changes in the conception of man himself. In the act of abstracting himself as an experiencing totality from a world left only as existence, man must also be committed to a vision of his own nature. In earlier times, this was a matter of a conception of God. In recent times, it has been a matter of conception of the nature of human knowledge and the possibilities of human powers.

Thus the side of the field of action I am calling "belief" involves three possible ways of influencing present activity.

(1) A transfer of structures from situation to situation. This is the abstract mode of *conception.*

(2) A view of the world which directs the scientific activity. This is the general mode of the *Weltanschuaang*

(3) A picture of the nature of man as he is in the world. This is the basic historical mode, and is an *implicit anthropology.*

Historically, method is a matter of *invention,* whereas belief enters the field of action as the *transmission and interpretation* of a complexity of ideas that posit the goals attainable by science. This is most clear in considering the significance of the various *schools* of science. The School of Chartres (12th century) was a major force in scientific belief. Here, it was a question of belief in science itself. The "awakening" of the European intellect on the occasion of its contact with the Greek sources of Western learning, and with the dynamic world of Islam brought with it a new orientation of mind. One of the fundamental features of this new orientation was a feeling for Nature as a total organism, a Goddess-power, the service of all life and existence. It was not something to be shunned, unclean and ungodly, but an integral part of God's creation. This notion was associated with a new appreciation of women and the spirituality symbolised by their nature.* On the side of invention, men like Thierry and Nichol of Amiens tried to bring theology into a system of numerology, geometrical symbols and abstract configurations, in correspondence with a feeling for the "new spiritual man", clear of mind, and hence sound of faith.

*C.f. Friedrich Heer *The Medieval World*

The honour given to Nature opened up a new feeling for natural forces. Probably influenced by Arab sources, the creative thinkers of this time conceived of a universe of energy or life, and cast this picture into mathematical forms.

It was not until the fourteenth or fifteenth century, however, that mathematical techniques were developed, and mathematical methods invented for doing much with such conceptions. As I mentioned earlier, the problem of the substantiation directed a lot of energy into problems of motion. The work of Bradwardine, Oresme and others evolved methodology to the point where problems of motion could be tackled. More importantly, human society was not yet receptive to such notions. The Middle Ages was a period of creative transformation, whose visible counterpart was endless conflict. Startling outbursts of creativity alternated with suppression, violence and political confusion. It was in the 12th century however, the time of the Crusaders, that the Latinized West became aware of the cultural, social and religious achievements of the Near East—especially those of the very lands that they sought to conquer. It appears to have taken three or four hundred years for the "new feeling" of human power, and the possibility of uncovering the *previously undiscovered secrets* of nature, to take hold.

One of the prime characteristics of the influence of belief in science is *search.* The classical formulation of the spirit of the scientific search, divorced from an effective method, is the *Faust* of Goethe. In his study surrounded by useless books and instruments he is left only with a devouring passion to find the secret of life.

Most histories of science portray alchemy, magic, astrology and so on as practices only accidentally instrumental to the progress of science. In the main they were great obstacles in the way of advance. There is another side. Alchemy embodied, a search, not only a theory. The immortalising elixir and the Philosopher's Stone were to lead many men into investigating all kinds of transformations, including those we now call chemical. In this light, alchemy was far more contributory to scientific progress than Ptolemic astronomy.

The history of science is littered with evidence of all kinds of search, which often led to results not to be foreseen by those who sought. Fechner, the German philosopher, deeply committed to a vision of the "withinness" or consciousness of all things, sought a way to combat the materialism of his age.* He invented the rudiments of psycho- physics to show a parallel correspondence between mental and physical events. This method turned out to be one of the foundations of modern experimental psychology, dominated by the belief that the only things worth talking about in science are physical, and all else valueless.

* " Man rejoices in, and boasts, of the unity of his consciousness, and thinks that in this he has something peculiar to himself, as opposed to the dispersed state of natural phenomena. He thinks this according to the Night View." *Day View versus Night View* (taken from a translation of a major part of Fechner's work in preparation for possible publication made by David Pendlebury).

The bringing-about of the physical science of the Seventeenth Century

The seventeenth century—or, rather, the period from about 1590 to about 1690—can serve as an illustration of our argument. We should remember that we are considering the total period as a. present moment of activity, *within* which we discern actions, and developments.

(1) *The Substratum*

The scientific activity was grounded in the needs of practical men - navigators, builders, merchants and so on. They were concerned with useful knowledge and practical inventions and not with things which they could not see, touch or manipulate. The expansion of commerce in the 16th century, involving exploration, called for accurate devices of navigation and computation. In England, many mathematicians such as Dee, Hood, Harriot and Briggs went out of their way to help navigators - there being no established institution for the teaching of mathematics to practical men in any form until 1590. In other fields, such as those of mining, irrigation and the craft of the optician, scientists were concerned with the *making of devices.* The speculations of the Middle Ages on possible forms of machinery were being realised: there was an economic and political demand for them.* It was from the self-interest of commerce that support for a new practical education came. Bacon and Descartes, also, were concerned with the practical points of science. Bacon was concerned that science should be *effective*—that is, lead to an advancement in the comfort of people. As we have said, Descartes was concerned with the attainment of a rational science of medicine which could constantly relieve physical suffering.**

* Out of this substratum of practice, too, came the automatic resolution of theoretical controversies. For example, the Torricellian vacuum, encountered in pumps and steam-engines, gave a practical sense to the meaning of the " void."

** "I have resolved to devote the years remaining to me exclusively in the endeavour to acquire such knowledge of nature as will enable me, in the field of medicine, to draw up rules of greater certainly than any hitherto practised" (translation of Kemp Smith) *Discourse on Method.*

(2) *The gradual invention of organised research*

Bacon, in his famous *New Atlantis,* had proposed a scheme for the *collective activity* of the accumulation of knowledge and invention, a theme echoed by Descartes in his writings. Both saw that specialisation was necessary, since truly empirical investigation required time and labour which could not be circumvented by any ingenuity of thought. An actual basis for this development was founded in 1590—one of the forerunners of the Royal Society, Gresham College in London, This had arisen out of the substratum of practical needs, and it was endowed by Gresham, a wealthy merchant With an educational programme. In it, such men as Napier (who invented logarithms) worked.

Another component was the "Invisible College", organised and conducted almost entirely through correspondence by the immense efforts of Samuel Hartlib (1599—1670); and the corresponding French Society, dominated by the thought of Descartes, run by Father Mersenne. The same period saw the emergence of scientific journals: *The Philosophical Transactions* from 1665 in London; the *Journal des Savants* in France; the *Acta Eruditorum* from 1682 in Leipzig. When we also include the content of the scientific practice of the period, especially as it was exemplified in England — atomism, the "frontal attack" on Nature, mechanical models and schemes of classifying phenomena — we have the emergence of a complex totality which we can call *collective empiricism.*

The traces of this development are the evidences of new kinds of organisation, and the more integrated and formalised field of communications.

(3) *Search and new beliefs*

The sixteenth century had imparted a legacy of a search for cosmic order in mathematical terms. Even Galileo, as Koyrere has pointed out, was inherently a Platonist, seeking for ideal mathematical forms behind observable phenomena. In astronomy, (his action was very strong, and ai its most powerful in Kepler. His exultation at testing the reality of mathematical harmony in the cosmos was not simply an abstract delight, but something inextricably bound up in his conception of God. The general belief in the *harmonious mind* can be distinguished from I he new kind of search represented by Kepler. No one can doubt that Kepler's numerological studies played an integral part in his passionate enquiries into planetary motions. He was evidently one of the many leading scientists of the time filled with the sense of hovering on the brink of seeing into the hidden workings of the whole cosmos. This was a new feeling, for these were men convinced of the power of reason, that mind could *intentionally penetrate* where previously only mystics had travelled by Grace.

Whereas Kepler saw God in forms of relationships between move ments and distances, Newton, being more in contact with the new actuality of science, saw God in a more physical way. Thus, for example, *space* was the "sensorium of God". This conception was to lead him to extend the space frame of an individual observer into a universal condition, where space became the single continuum and reference frame for all motions. God was not *in* the world, but the world was seen as a whole, all at once, by God. Thus God remained transcendental, yet in terms of experience, continuous with His creation. This conception was fundamental to the religious ideas which were of such a deep import to Newton, and many of his compatriots. It is no accident that Newton gave much time to theological studies and wrote extensively on the subject. Here also, we have an exemplification of an implicit anthropology. Newton became part of that tradition which led to Locke, Berkeley and Hume which concerned itself with a critique of knowledge of mind. Newton's image of God involved a rejection of the Christian mystery of the Trinity. His concern, like that of Descartes, was with the inference of God through the workings of nature and the power of the human mind.

This corresponded very well, it may be noted, to the development of co-ordinate geometry by Descartes. Denying any attribute of extension in the observer of the world, the world was left as pure extension and movement. There could be no special locus in the world, since mind and matter could not engage or touch anywhere. Hence the abstract technique of the Cartesian co-ordinate system was rendered meaningful in terms of the nature of man and his knowledge as well as in terms of the world.

(4) *Human destiny and the development of mind*

This period, which saw the ascent of a conviction in the power of the human mind, was also one of the decline of religion. It was to lead to the 'modern philosophy of mind and to the doctrine of universal progress. In general, philosophy is "based on a faith in the possibility of objectifying mind. Only in this way can discoveries of men be communicated and formulated. Philosophy has had the role of creating a language about the workings of mind. Though its avowed content may be existential, it is in practice at the meeting point of experience and existence. Its role has been to act as an aid to *reflection*—which is the pre-requisite of objectifying mind.

The emergence of organisations for research was evidence of a conviction of future results to be attained by the human mind. Hence arose tfie concern with the *methodology of reason* which we see so clearly in Bacon and Descartes. For them, it was reason first, and science as a result. That they diverged in their views on the training of reason does not concern us here. Both socially and individually, there was a field of action which had the property of *enabling a development of mind* to take place. This must be explained.

It is assumed that, if people had come across the "right" notions and had had 'the "right" motivations "modern" science could have arisen perhaps thousands of years ago. Various explanations have been put forward for the tardiness of scientific development—economic, geographical, social, political, religious and so on. The argument we are making is that the human mind was not .ready for the activity of science on the scale in which we have known it recently. Complex patterns of thought had to emerge before there could be the situation where creative man would devote themselves to puzzling over the structure of the natural world as scientists do to-day.

The action of the seventeenth century was an outburst of creative activity which made new and more widespread demands on the minds of people. These demands were not on a "higher level" than before, but were of a different kind. Man had to gain access to the "hidden world" beyond sense-perception through a combination of the forms arising in his mind and action in the world. In reality, this is a paradoxical situation, and we are reaping the legacy of problems arising from the confusion of that time. To-day, also, we confront a situation where we have to organise creativity in science. The common experience of brilliant minds becoming stale at the age of 30 is partly due to the imbalance of education in thought. On the other hand, we have a world situation— not only in the complexity of science—which we are unable to handle in terms of the categories of thought bequeathed to us.

In brief, our thesis is that the development of the human mind is the key to the fourth component of the action of science in the seventeenth century. The structure of action enabled the effort of development to be supported by a basis of socially useful activity. Within the field of action, man's changing attitude towards his own place in the scheme of things, and towards the possibilities of his nature, were a meeting place for the ground of influences co-present with science in the same moment of history.

Understanding Present Science

By putting our attention on a present science as past, present and future in a unity of action, we can derive six secondary categories, which are mostly self-explanatory.

(1) *The Identifying Image*

The transition from past to future is characterised by a certain kind of action within the present moment. This is best seen in organisations devoted to science. The Royal Society of London, for example characterised a present moment of science by its persistent experimentation within the framework of the corpuscular theory of matter. It is pertinent to observe here how there can be co-present different identifiable present sciences. Go-present with the Royal Society was the more theoretical Academie des Sciences in France, and the conservatism of the universities of Oxford and Cambridge. The Universities were. in a sense, operating in the past. On the other hand, Newton was the spokesman of the future, a disruptive one for the Royal Society.*

* Its amateur membership were hardly able to grasp the complex mathematics of the Principia, being used to empirical researches devoid of synthetic theorising—after the model advocated by Francis Bacon.

The historian allows for a differentiation of action, more or less relevant to the present moment.* His concern is with what was made out of the past in the present moment of recurrent activity.

* The notion of a "simultaneous present" for all scientists of a particular lime is a total misconception. Ideas of time already transcended in physical science still persist in historical thinking where, above all, they are totally misleading.

These are expressible in an image of the period, which is closely related to the dominant notion of the time. In Kuhn's terminology, this is the *paradigm.*

(2) *Environmental Relations*

The changing future operates upon the legacy of the past which has entered the present moment through an interplay of men, groups and ideas. Thus pressures arising in the general environment enter the present activity of science through men belonging to science. For example, Descartes was impelled by his recognition of the growing scepticism of his time, to find a rational basis for belief in God and the attainment of certain knowledge in general. This led to a critique of the authorities of the past.

Within the same category, one should include the dynamics of relations within science. Take, as an illustration, nineteenth century geology. While geology was emerging as a distinct area of study, there was no agreed method of procedure for interpreting the traces of the past in the present moment of terrestrial activity. Controversy raged between the "Uniformitarians" and the "Catastrophists": the former advocated the extrapolation of present intensities, and even rates of change into the past; the latter argued that one must explain present features of the Earth's crust by positing a series of violent catastrophes in the distant past. The two schools were represented by Lyell and Rutland respectively. Both stumbled over the problem of the "erratic blocks" scattered over Europe and North America sometimes hundreds of miles from their origins. It was the Swiss geologist Agassiz who introduced the explanatory notion of the Ice Ages*: in Scotland he was able to perceive the same glacial traces as were clear in the Alps so familiar to him. Initially, his explanation—that the erratic blocks had been carried by vast glaciers covering a great deal of the two southern continents—was rejected by both Rutland and Lyell. Agassiz was the agent of the future. In time, Lyell grew more and more catastrophic, and his opponents more and more uniformitarian: a general environ mental agent intervened in the form of travel and world-wide observa tion. Experience of the complexity of geological actions resolved the legacy of conflict and brought to birth a consistent science of geology.

* Before Agassiz, Wrede (1804), Gruithuisen (1809) and Playfair (1815) had come to the notion of great glaciations occurring in the past, and had even, in the case of Wrede, applied this notion to the erratic blocks in Northern Germany. Agassiz himself acknowledged Goethe as his forerunner. The notion of a great Ice Age was only clearly established through a series of lectures by the poet-scientist Schimper (1835-6), and it then exemplifies the “identifying image" within the domain of the scientific thought of that period.

Clearly, these environmental relations can be explored in greater and greater detail and complexity. Without the identifying image, all form in a present science can easily be lost.

(3) *Zeitgeist*

A present science acts in the context of a general attitude towards man, the universe and God—which is commonly referred to as the "Zeitgeist" or "spirit of the age". In science, the Zeitgeist gives rise to an orientation of mind which allows the future to affect the legacy of the past. If there is any truth in our notion of the future "overshadow ing" the present moment, then there must be a way in which the present moment can become opened to the demands of the future. This, we suggest, is what the Zeitgeist in science does. Such a proposal will only be acceptable to those who recognise the presence of an orientation of mind in the present moment which cannot be explained in terms of prior events.

The feeling for "progress" in the nineteenth century was the condition for the emergence of the evolutionary sciences. Evolutionary notions had been entertained for thousands of years. But it was not until the general mind of man was turned towards time and progress as interrelated and operating in the present moment that any advance could be made towards a science of evolution. Significantly, the "idea of progress" is one of the most confused we have. Conceptual discussions are not enough to give an account of it—indeed it hardly makes sense in the terms in which we speak of it. The "idea of progress" is more a general *feeling*—and that is why we have spoken of this in terms of an orientation of mind, rather than as some content of mind.*

* C.f. Toulmin and Goodfield *The Discovery of Time* ". . . the critical period was the twenty years between 1810 and 1830. . ." (p. 233). The philosophers of that period did us a great service by insisting on the progressive character of temporal change." (p. 235).

(4) *Historical reality*

We would all agree that, without science, the world would have been different. The whole shape of our contemporary existence is permeated with the results of the actions of scientists.

The scientific revolution of the seventeenth century was a component of the complex origin of the modern world. Reaching further back, the science of the Hellenes, as part of their general enquiry into man and nature, was to contribute uniquely to the development of the Western mind—it was in Greece that the idea of *reason* was born and nurtured.* Yet further back, we encounter the obscure origins of the Promethean gifts of fire, the working of iron, geometry—and language. Language before all, because with language comes the power to represent, to order and analyse experience, and find within the mind the mind's reflection of the world.**

* As something independent from the higher intuitive faculties commonly implicit in early philosophies. We should also mention that the doctrine of causality was first put forward by Buddhism.

** The extreme *identification* of language and thought as in the works of Max Mullcr, we cannot agree to. However, the work of such linguists as Lee Whorf *Language, Thought and Reality* and anthropologists as Levi-Straus *Structural Anthropology* have clearly demonstrated the world-conceptions inherent in the use of language

Under this category of "historical reality" we are concerned with science as an *act of origination* in human life. The historical reality of science is to be seen in the "new causes" which it introduces into history. An obvious instance is the release of nuclear energy prior to the Manhattan project. From that moment, the 'probable future' hung in balance an uncertainty in which we live today. As another example, we can take the psychological investigations of the twentieth century. These have made available possibilities of conditioning thousands of people, possibilities just beginning to be exploited by advertising.

There is a freedom in science which is significant for the future. Today, still the tendency is for most scientists to treat the future of science as the statistical outcome of the interplay of unrelated present researches, and by ' natural law' to be progressive. This attitude encourages irresponsibility. To the measure that new causes are intro duced into the future, present science is responsible. This responsibility can be placed to the intentions of the present moment concerned. In this sense, Newton had a responsibility for the decay of belief in the eighteenth century. The intention of his physics was to find a place for God in the Universe, but behind this was an intention to advocate a theology "without mystery". His failure—the reversal of the desired result—is an ethical lesson.

Science also breaks through the barrier of its own past. In our own century, present science is breaking through the barrier of centuries of absurd beliefs about space, time and matter toward a new world-view. The origin of this break-through is in the creativity of the present moment. It is in the present moment that responsibility lies.

(5) *Expansion*

In certain present moments, there is manifest an expansive phase of science, resulting from programmes for advancement for which the "time is ripe". Examples of this abound: the flourishing of Islamic science, the outburst of the Renaissance and the revolutions of our time. In all these, the legacy of the past has been sufficiently prepared for new lines of action to bear fruit. The undercurrent of critical examination devoted to classical ideas at the end of the nineteenth century, together with the emergence of electro-magnetic theory and thermodynamics was the fertile ground for the idea of relativistic physics to take root.

There is the notion that modern science in general is expansive. This is valid, if one allows for a scale of present moments. Modern science erupted out of the Renaissance, which had gathered together the material of antiquity, the contributions of the Arabs, and more recent notions of alchemy and astrology; we are still bearing the fruit of that. Since the Renaissance, however, there have been sudden periods of preparation from which new developments have arisen. The expansion since the early seventeenth century has not been a single stream—unless we define this very diffusely. The new sciences of biology and geology had their own, later, periods of preparation. The independent build-up of mathematics in the nineteenth century is a case in point- this was the source upon which most of the "new physics" drew.

(6) *Concentration*

Within a present moment of science, there can be an action of refinement whereby the legacy of the past is distilled and understood.

This has already been referred to above in speaking of expansion. It is a reflection of the general historical principle that only by the understanding of the past can the present be understood. The character ising feature is awareness of the future. When scientists are aware of the direction needed for the advancement of science, they have the necessary task of comprehending the situation in which they find themselves. This is constituted out of the past. The slow process of criticism, interpretation and clarification results in the *refinement of method* in the present moment.

This is well exemplified in the medieval *reflections on method* which were the precursors of the empirical science of later centuries.* It is an action that is under way in our time, when, more and more, the events of the past fifty years in physics have become the object of study. The philosophy and the history of science are themselves manifestations of this action. However, reflection *within* the present moment of science is rarely strong. Yet this is the essential mode of concentration, to struggle to understand what we are doing.

* Described in Crombie *Augustine to Galileo Volume 1*

Authentic science is both firmly based in scientific practice, that is, in tangible history, and also in the origin of a special freedom. For this reason, the understanding of different men can be *shared* through a participation in science. This is radically different from the common assumption that we understand nature better because we stand on the shoulders of many generations of earlier scientists. Our understanding is *different not greater.*

4. THE SELF-INDUCTION OF SCIENCE

The circulation of scientific material within civilised regions of the ancient world, and within the scientific communities of to-day, with gain and loss, usage and adulteration, development and decay, makes up the visible history of science. It includes raw observations of phenomena, classifications, empirical techniques, and all that has to do with the retention and ordering of recurrent features of the phenomenal world. As I have said, this is akin to the vehicle of science through which development occurs. Development requires an organisation of material and activity which transmission alone cannot give. Recurrent notions, the rise and fall of the dominance of various attitudes to the world, creativity and the influence of men and groups: all of these, taken together, have the common feature of being modes of organization.

Recurrent notions have a breadth of applicability that renders them ideal objects* in the history of science. The interplay of attitudes to the world determine whether or not the scientific activity is considered to be of importance, and hence its power *in a culture.* It can also deter mine what form the science can take.** Creativity which leads to a transformation of ideas and material involves a new organization of the content of science. And the power of man and groups is directly related to their organizing influence in the realms of thought and action which can largely determine the "style" of science at any period.

* They are morphologically identical to a present science.

** Take, as a simple example, the differences between Greek and Arabic science.

The role of recurrent notions

To exemplify the role of recurrent notions, we can turn again to atomism. It is commonly supposed that the atomism of Leucippus and Demoeritus originally represented an interpretation of the philosophical duality of Being and Non-Being, discussed by Parmenides and others. Atoms are what is, or Being; space or the void is what is nothing at all, and Non-Being. However, that may be, the atomism of the Democritean school was a step ultimately to converge with other forms of thought towards scientific atomism.*

* The divergent aspect of this theory should also be taken into account. Taking the total view, it was as much a part of divergent philosophical thinking as Parmenides' ontology. This aspect of the situation corresponds to the broad evaluation of science discussed in section 2.

The *De Natura* of Lucretius transmitted the basic idea into the Latin world. However, it was not generally adapted as an explanatory principle until the sixteenth and seventeenth century. Of course, there was the atomism of William of Conches of the School of Chartres in the 12th Century based on the Timaeus ; the logical atomism of Ockham and the Nominalists; and the atomism of Giles of Rome (around 1300) based on the structural theories of Avicebron in which every level in a hierarchy of forms (in the Aristotelian sense) contained ultimate units, the division of which resulted in reaching a different place in the hierarchy.*

* For a full account of the doctrine of Ayicebron (or Ibn Gabirol) cf. P, Duhem *Systems du Monde tome 5.* It is interesting to note that this structural approach has entered into rigorous modern science with the topological representation of discrete space-time.

All of these played a part in the life of the idea. The mainstream, however, is exemplified by Grosseteste and Roger Bacon whose theories of heat as a form of atomistic motion were carried over by Nicholas of Cusa and Giordano Bruno to the beginning of the seventeenth century, and the interpretation of physico-chemical behaviour—burning, mixing combination, reactions and so on—to Boyle and others in that century.

The atomistic idea, from being a force in the history of ideas as a structural total conception as well as a restricted model of behaviour — became an accepted mode of explanation in the beginnings of modem science. There are modifications in the original Democritean conception. F or example, the early chemistry of the eighteenth century began to distinguish between classes of atom by means of the systematisation of chemical phenomena, and through the germinal conception of "elements", Newton's gravitation centred the beginnings of a conception of forcefields, which was in the nineteenth century to lead Faraday, after Boskovic* to suggest that atoms were the foci of lines of force, and not discrete and solid bodies. Maupertuis, following Newton's lead in the "Optiks", ascribed all kinds of properties to the ultimate corpuscles including even sensitivity and memory. This is another example of the twofold nature of the content of science, for here Maupertuis enters the field of conceptions such as that of the "life-monads" of Vaiseka Buddhism, and the acts of divine will, bursts of energy into manifestation, described in the Ash'arite school. These holistic, vital conceptions were confined within the atomistic formalism by the fixation of a simple atomistic concept of the ultimate 'bits' of matter. By the seventeenth century, the great discussions of the Arabic schools — such as those exemplified by Avicenna and Avicebron on the relativity of "corporeity" - had faded into oblivion. Hence matter was treated just as 'stuff'. There was an implicit notion of this stuff being homogeneous. The differentiations of our experience came about through the conjunction of primary *inherent* qualities, and those secondary qualities contributed by the observer — i.e., by mind. This crude fixation is exemplary of the way of science, which needs working conceptual tools appropriate to its present state of investigation. The convergence to a restricted view (not, be it noted, really more precise — for it is often very ambiguous and even self -contradictory) reflects the action of a present science in selecting out of the past what is useful for its intentions. Science does not prove what is or is not valid about a notion. The working concept of science reflects the original notion info the context of the progress of present science. It acquires a particular form from what is going on in science.

* 1711-1787 A Jesuit scientist who showed a remarkable critical ability: he showed that the physical notions of Newton's *Optics* were quite untenable and also anticipated many nineteenth century conceptions of matter

Interestingly, Maupertuis had in fact used the main principle of holistic thinking analogy— to derive the attributes of his atoms from observations of the properties of living entities (especially those later to be connected with the science of genetics). *Implicitly,* he was "explaining", in a holistic manner, the properties of the postulated "molecules" by means of the properties of living cells. *Explicitly, h*e was "explaining", in an atomistic manner, the properties of living cells in terms of those of the molecules. This asymmetry is significant. It permits development, and shows how the various recurrent ideas can *all* play a part in a single theory, while that theory retains its unique structure.*

* C.f. also Stephen Toulmin's *Foresight and Understanding.* He asks why atoms are not explained in terms of living cells as well as vice-versa. If we grasp the notion of the intricate blending of basic modes of thought in any one theory, we can begin to see that it is in one sense already being done. and in another, why it should not be done.

What is central here is the establishment of atomism as a *mode oj* explanation. Explaining is part of the *fundamental act* of science. Its irreducible components are connection and asymmetry—i.e. there has to be the introduction of a specific connectivity or law between *otherwise* unconnected event's, and the character of the mode of connection distinct from the character of the events. We call explanation an act because it always introduces a new element into the structure of scientific activity. Within a present science, there is often controversy over a mode of explanation. For example, the Cartesians criticised the Newtonian cosmology because it "did not explain" the phenomena — it was only mathematics and *not physics.* From our perspective, we see it as more that Newton wanted to do different things from the Cartesians. The cognitive constituents of science are integrally linked to the purposes engaged in the activity of science. Thus, concepts become "reified",* through the common usage which employs them in purposeful action.

* Boring in *History, Science and Psychology* uses this term to denote when concepts are believed to refer to something objectively real.

It must be stressed that explanation only refers to the field of scientific material. It is not a resolution of metaphysical problems, and never can be. The recurrent ideas are structured within the relation ship of a theoretical explanation, anchored to a domain of scientific material, and coupled with a heuristic aim. The endurance of the ideas is maintained by such employment, but they do not depend upon science alone, Hobbes' view of social man is as strongly atomistic as the "mental set" of the Royal Society in the Seventeenth Century, whose members could not think outside a corpuscular universe. Recurrent notions have a life independent of science, and should be seen as something more than the metaphysical background of the activity of science.*

* In the field of the history of science, these notions are often referred to a “regulative principles " after the manner of the great Cambridge geologist and historian-philosopher of science, William Whewell. Though the “principles" are different in form from the recurrent notions they refer to the same metaphysical life which is one of the forces in the life of science. The regulative principles, however, are usually derived from a purely scientific context, and in the situation of convergent trends within science t owards some mode of explanation.

I have talked of the endurance and significance of recurrent notions, not simply of enduring ideas. The difference is that an idea that endures has a beginning and a continuance only. Recurrent notions cannot be localised in a time of origination. Pure origination occurs only with truly creative innovations -those which mark turning points for science in one of its domains. Surveying the totality of scientific work one sees the life of the recurrent ideas throughout. They are dynamic, and live through an interplay of influences. The atomism of the ancient world was not one doctrine—i.e. reducible to a finite set of propositions—and if is only in the theoretical formulations of some period of science that there is the appearance of a single notion (but I have suggested that multiple potentialities lie behind the surface, and play an implicit part in actual theories). These ideas are themselves organised, and possess their own structure. They grow richer in content and significance in the fi eld of science as they enter into explanation.

Explanations exercise power because people find them convincing or meaningful. The nexus of recurrent ideas is intermingled with the changing dominance of men and groups who have differing attitudes towards the nature of science, and who reflect the interests within cultures which change from period to period.

We must also not forget that human experience transforms the significance of events within its totality, and original doctrines themselves grow and develop. There is no purely existential conception of the universe, and the elusiveness of the foundation for the validity of interpretation represents the inner dynamic of ideas which corresponds to their recurrence in the world of action.

We have already touched upon phenomena of the history of science which cannot be understood without reference to patterns of action, or structures. First of all, there is the general emergence of that self- perpetuating method of combining thought, perception and action which we identify with the "scientific approach". Presented in that bare form, it is barely distinguishable from technology, and, indeed, the emergence of organised technology is inseparable from the emergence of theoretical The pattern of action of the scientific approach has been effective only in contexts where the conceptual links made by theory have been expressible in action. Science finds itself midway between philosophy and the rule of thumb of the practical engineer—that is, between speculation on the nature of things and getting things to work without really knowing why. By *explaining* things in a different way in ordinary conceptions ideas become effective in action. Conversely, ideas can be seen in a different light, and hold a different place in man's thinking. Finally, the natural world itself changes in significance.

Transformation

It is in this way that the method of science is self-perpetuating. Engaging, first of all, in the forces of thought and of effective action, there is a dialectic of tensions which reserve an arena of freedom within which science can play a significant role. Secondly, science itself has I his kind of pattern within its own domain, developing in relative independence conceptions of the structure of things and the clarity and details of what is known about them. Historically, it makes a track of interpretation and action that mirrors the changing significance of the natural world in human experience. The prime example is the transformations made in our outlook on the world by the emergence of modern astronomy and evolutionary theory in geology and biology. Here even the assessment of our own significance is changed. It is, indeed, the major example within thousands of years of the meeting of science with human history.

The third way of self-perpetuation is through certain patterns in social activity which are centred on a *scientific community.* These primarily involve an interplay of rotes within the dynamism of science. Here we touch on the creative acts of individuals, the meeting of influences which we discussed in the last section, and the interplay of groups and influences which constitute the acts of commitment made by science. When commitment leads to action we .are involved in the dynamism of past and future. It is by this commitment that past and future are distinguished, and it is by a transferring action that they are related. Without this, science would be constituted out of that "causal nexus" which Wittgenstein dismissed as "superstition". The notion can be illustrated by the consideration of creative acts in science.

We suggest that a creative act marks a discontinuity in the formalised structure of science, a fracture in the crystallisation of knowledge and conceptions which reveals new possibilities. At the same time, the transformation made possible by creativity integrates together both anterior and posterior states of science and defines them as such. It is this which is often forgotten. In the continuum of science— constituted of accepted theories, areas of knowledge, techniques and directions of interest—a revolutionary theory that gains acceptance is treated only as a change from old to new, in which the new is an improvement on the old. For the individual concerned, the old enters into the emerging idea, changing its meaning, but giving something essentially its own to the future. The inner dimensions of theories—what we have called the total, structural nature—are no longer alien to the forms of expression. What happens is not simply a change, but a. reinterpretation of the significance of the ideas and knowledge involved in a new form of scientific action.

Newton, in the development of his mathematico-physical theories of motion and gravitation was not simply making a change from an old mechanics and kinetics to a new. Material that had remained relatively unnoticed especially in the work of Kepler which was extremely difficult to render in such a way that the various ideas which emerged over years of work could be disentangled—was brought into a highly developed mathematical field. Though most of the work of Kepler was at least known about before Newton*, it was not until after the publication of the *Principia* that people saw how Kepler's work *made sense.* Put in a more realistic way—they were able to see what *could be done* through such notions, because Newton had demonstrated it. We can hardly maintain, either, that somehow Newton's actions were "contained" in the theories of Kepler. Newton had introduced "new causes" into the present moment of science. This was a transformation of its morphology, including its orientation towards the future. We should also mention the role of "accidental discovery". This can be looked at in two contradictory ways. In the one view, situations arise in laboratories and so on which present to scientists numerous instances of peculiar phenomena, cognition of which would lead to rapid advances. As “time goes on" the accumulated number of likely situations so increases that eventually someone must, and indeed always does, spot the significant factor. In the other view, the new developments are already destined for realization and influence the attention of scientists in the present moment. Eventually, someone will recognize the significant element. Since others are also influenced from the future, they will be able to recognize the significance of the discovery, so that it will not fade into oblivion. Of course, the two views are complementary. The former views the present action in terms of the past, whereas the latter views it in terms of the future. We must emphasize that both views are intrinsic to the act of the historian.

* CF. Russell "Kepler's Laws of Planetary Motion, 1609 - 1696" The British Journal for the History of Science, Vol 2, Part 1, no. 5

The core of a present science is an act which can transform the construction of the situation. This can be tangibly exemplified by the accidental discovery of X-rays leading to the transformation of the Crooke’s tube into an X-ray generator. Parallel to this is an opportunity for transformations in the understanding of individuals, and beyond them, in the common understanding embodied in the vehicle of active understanding. Needless to say. individuals may fail to enter into the change of understanding!. The numerous conflicts within the history of science, representing a tension opening up an area of freedom, usually result in the protagonists becoming losers or victors, and the victors usually become more strongly entrenched in their formalisms of thought.

The act of science is *present* in the structure of knowledge, action and purpose, which is shared in by a community, that enables work to go on in diverse fields, and experiences to be brought into stable representations. This act has a peculiar kind of freedom. With this freedom comes a special responsibility, for science is a *means to power*. Discovery gives new possibilities for action—not only by the action of scientists, of course. With new kinds action comes a new understanding. We can only understand through what we can do.