Alfred Korzybski Memorial Lecture 1969

ON THE FRONTIERS OF SCIENCE: THIS HIERARCHICAL UNIVERSE

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I wish to say at once that my theme tonight is more appropriate than I realized when I chose it. At that time I was not aware how much my topic overlaps with Alfred Korzybski's emphasis on levels of abstraction and on the importance of asymmetrical relations in generating order of various kinds. He would surely have welcomed what I have to say.

When I speak to a new audience I like to devote a moment at the start to explaining the relevance of my theme to the plight of mankind. That seems to me right. Moreover the young follow me better if I do. They demand immediacy in life and thought; everything must express human vitality and be seen to serve human needs. That I accept.

What, then, has hierarchy to do with the general disorientation today? My answer may surprise you. To understand hierarchy is one way to understand ourselves. Each of us is a hierarchically constructed organism; our anatomy, physiology, thoughts, and actions are all organized in a sequence of levels. When not pathological the human person is, like all viable organisms, a differentiated hierarchy, a superbly coordinated system of hierarchies: in our case glandular, neural, muscular, and skeletal, all interdependent. When we are ill there is a failure of coordination at one or more levels in these hierarchies, and the clarification of the relation of body to mind and of psychosomatic illness requires a hierarchical approach. Guilt, hypocrisy, heartbreak, and so on, are lesions in the hierarchy. Hierarchical structure is the basic feature common to matter and mind.

If we say 'God is dead,' or 'nihilism is destroying the human tradition,' we mean that the apex of the hierarchy has disintegrated. The dominant element in the neural hierarchy, the component of the brain-mind which normally exercises supreme control, has lost its traditional coordination through religious convictions, but has not yet acquired the new mode of coordination, or system of basic principles and attitudes, appropriate to a quasi-scientific age. The human individual and community are therefore threatened by disorder at many levels.

Some pathologies are self-limiting and self-curing, but humanity cannot establish the stable coordination characteristic of all viable species because it does not yet understand the factors which in man should sustain the proper hierarchical coordination. We must hope that there exists, in man, as in all organisms, a tendency towards coordination. Our sickness is ignorance of our own true natures, that is, of our proper coordination; we cannot see ourselves as we should be: a highly complex but marvellously coordinated hierarchy. An unbalanced science is failing us, for it cannot yet point to the formative processes which can restore harmony. We lack an image of hierarchical man.

Thus my theme touches the core of human failure during this century. Moreover it is timely. For, as we shall see, and this is my leitmotiv today: the 1960's are the decade of hierarchy, the first preparatory period of a coming science of structural levels. I believe that a natural philosophy of hierarchy can and will assist us in achieving that deeper understanding of ourselves of which we are in desperate need. Mankind will not achieve a stable unity until everyone — in all lands — shares a common understanding of what it means to be human.

Let me tell you of a recent experience. It was a daydream reflecting my philosophy and my view of the frontiers of science.

I found myself in touch by radio-visual-telepathy with one of the Recording Angels in the Heavenly Mansions. She told me that it was her task to record in a parchment volume labelled Homo Sapiens the things we knew, that is, those scientific discoveries made on earth which were valid, and would never need correction. They were definitive identifications or classifications of natural forms, structures, and processes — types of ordering in three-dimensional space. As she turned over the pages I saw the Linnean classification of organic species (1736), and expressed surprise. 'You're right,' she said, 'God scolded me for including that; it needs some improvement. But apart from that one mistake, every item is absolute, an unassailably valid permanent truth. Take the identification of the closed ring of the benzene molecule (1865) for example. No Einstein will ever turn up showing that the benzene molecule is not a closed ring after all.'

I saw in her pages the periodic classification of the chemical elements (1869), the identification of the asymmetrical carbon atom (1874), the classification of crystal symmetries (1820/90), and of the quantum mechanical symmetries and groups (1930), and the identification of the equilibrium forms of the DNA helices in chromosomes (1953). Her records showed a trend from simpler to more complex patterns, and from physics to biophysics.

Moreover she pointed out that these items of absolute knowledge were cumulative, and fitted together. Each provides a reliable stepping stone to the next. Thus we could pass on, step by step, to progressively more complex identifications of ordered structures, through bacteria, cells, plants, and animals, recognizing the characteristic structural hierarchy of each biological group, until we finally identified those crucial structural and global features of homo sapiens which determine man's unique qualities, potentialities, and powers: religious, aesthetic, intellectual, and scientific.

She stressed that this advance in the identification of structures transcended the naive nineteenth century antithesis of 'mechanism' and 'vitalism'. Man is not a XIX century machine, and nature is not known to be divisible into two separate parts, nonliving and living, with a discontinuity between them. Dogmatism about these doctrines was silly; we knew too little about both realms. The awkward fact, which some neglect, is that we do not possess a satisfactory theory of complex partly-ordered systems, so dogmatism on basic issues cannot be justified.

I saw the significance of her record. It proved that the advance of science was not — as some have suggested — merely the perpetual falsification of old theories by new ones. On the contrary, for a hundred years physicists, chemists, crystallographers, and recently molecular biologists had been steadily accumulating valid identifications of spatial structures and processes. Moreover this was a self-checking autocatalytic process, each achievement easing the identification of the next piece in the three-dimensional jigsaw puzzle of natural structures. The pace would tend to increase and, if the accessible realm of structure is finite, as I believe, one day science will reach the end of the road, an awesome possibility.

Then she turned a page and called to me in excitement, 'Look at this! Here is 1960/70. It's on a loose sheet, because it isn't yet a final achievement, but I've recorded it as a beautiful example of the simultaneity of ideas. In three sciences: physics, biophysics, and cosmology, closer attention is now being paid to levels of structure and process.'

There is no mystery about such simultaneity. When the advancing frontier of thought, determined in this case by intense research on structures of several kinds, comes near to a major peak, many scientists independently notice the upward slope and start looking in the same direction, though in the fog of their ignorance they cannot yet see the peak clearly. Attention is drawn to a particular class of problems before it can be correctly formulated, and a convergent movement begins. When a major unifying idea is latent in several neighboring realms, workers become aware of its importance by an act of imaginative judgment though they cannot yet express it precisely. The idea is vaguely in the air, before it becomes clear. In the 1960's hierarchy is in the air.

This simultaneity is an old story in the history of science, but owing to the intensity of research today and to our heightened awareness of past, present and dawning future, the recently increased attention to levels of structure is unmistakable. So the 1960's may be called the preparatory decade of hierarchy. Some scientists are coy about such conjectures about the future, but I find them instructive. Right or wrong, one can learn much from them. They are interpretations of the present which suggest problems for research.

My angel emphasized the fundamental character of hierarchical ordering, saying 'It was one of the

first things God made his mind up about. The various forces: nuclear, electromagnetic, gravitational, and so on, are not fundamental, but arise from the relations between certain levels in the inorganic hierarchy. So the first outlines of a general theory of levels may precede a definitive unification of the field-particles of physics. To understand the bizarre collection of so-called particles one must not only classify them in levels but understand how these levels arise.'

With that hint, she went off the air, and my angelic communing was at an end. She left me stimulated, but lonely. Angels, like Gods, serve a purpose: we invent them for our comfort.

Now what is a 'hierarchy'? How clearly can we see this idea? Since I am now entering the realm of science I must stress that I am speaking as a frontiersman without the authority of science, which is often gravely misused. For a professional malady of scientists is to exaggerate what is known. Remember, please, that this paper is a disciplined conjecture, not a survey of established fact. We are at a still disputed frontier. More than that: there is always a risk of guerillas challenging us behind the lines; there may be faulty unconscious assumptions in what naive minds believe is already firmly established territory.

'Hierarchy' is an old philosophical term acquiring a new scientific meaning in the context of XXth Century knowledge of spatial structure. I cannot here trace its history, from its original application to the sequence of higher and lower levels in the ancient angelic and priestly hierarchies, through the mediaeval 'chain of being' from God at the top down towards the last material atoms, to the late XIXth Century, when the idea began its comeback as a term used in the analysis of language and science. Since around 1860, its use in science has been slowly growing more frequent, particularly from 1920 onwards, until the explosion of the 1960's.

In the sciences concerned with three-dimensional spatial configurations and their changes, such as physics, biophysics, and cosmology, a 'structural hierarchy' may be defined as 'a spatial system displaying a sequence of separable levels of sufficiently stable structures or processes, each level being paired with at least one other level, a unit at one level being composed of parts, each of which is a unit at the next level, and so on, until possibly some ultimate indivisible unit is reached.' In structural hierarchies there is really no up and down, only larger and smaller. A structural hierarchy is a system of sub-systems, from larger and more complex to smaller and (normally) simpler ones. One may speak of 'higher' and 'lower' in the hierarchy, but in physics or biophysics one means larger and smaller. Such terms as 'stratified stability', 'levels of complexity', and 'causal levels' have also been used.

Each pair of levels is connected by a one/many asymmetrical relation, one whole to many parts, characteristic of the pair. The presence of these one-many asymmetrical relations takes us out of the realm of 'mechanics' in a strict sense, into that of what I call natural geometry, and gives the hierarchy its characteristic branching structure, each larger whole being usually divisible into many smaller parts. The doctrine of atomism has until now involved the assumption that the properties of all particles are always the same, wherever they are. It appears that may sometimes be wrong. Some of the things we call 'particles' may possess, or seem to possess, different properties when several of them are arranged in an ordered system by appropriate asymmetrical relations.

Notice a remarkable property of structural hierarchies: they are interesting! They possess immediacy, being beside us in 3-space. Moreover one cannot help wondering how they came into existence. If this universe is seen to be hierarchically constructed, it at once becomes more meaningful, for this kind of arrangement provokes the question: Did some master-mind set this his stamp on it from the beginning? If not, when and how did this arrangement arise? Do the most comprehensive laws of nature generate hierarchies, when circumstances permit?

There is another reason for hierarchies being interesting. Much of our thinking is hierarchical. For example, we divide periods of time into millenia, centuries, decades, and so on, down to days, hours, minutes, and seconds. This is the way in which we naturally classify things, including non-quantitative ones, like the globe, continent, country, county, town, and street. So at a semi-conscious level, hierarchies are congenial; they are like our own bodies and minds. This is right and proper; we are part of nature.

Now a few more definitions. A 'level' in a structural hierarchy is 'a separable layer composed of entities all possessing the same status'. But what does 'the same status' mean? To answer this we must notice that it is not single levels but pairs of levels which count, for all spatial order in physics implies at least two related levels: the separate parts at one level forming an ordered arrangement

or unit at the next larger level. Thus 'same status' means 'similarly related to some other level'. So we can define a 'pair of levels' as 'two separable layers of entities connected by an asymmetrical relation characteristic of the pair', like 'larger than', but more specific.

A 'unit' is 'any physical or biophysical system occupying a level, usually marked by a characteristic type of three-dimensional ordering of its parts, and forming a part of the next larger level'. (Units have also been called 'orgons' and 'wholes'.) I shall come later to a crucial question about these units: Do unit or system laws exist which override or go beyond the properties of the parts? In what sense, and when, are wholes greater than the sum of their parts?

But a warning about these definitions. At the start of a new enquiry one is in the dark. One cannot know for certain what definitions will prove the most useful. Mine may not always be the best. Indeed it is unlikely that any definition is equally suitable for all types of structural hierarchy: physical, cosmological, biophysical, etc. Moreover, I suggest that the term 'hierarchy' should only be used where there are a finite number of separable but paired levels, and 'gradation' employed instead where there is a continuous sequence, as in turbulent regions of continuously varying sizes in a fluid, or in the continuous black-body spectrum.

Light may be thrown on the idea of a hierarchy by considering what it is not. When I assert that the universe reveals a hierarchical structure, I mean that it is not one vast disordered collection of similar entities, all enjoying the same status, like the identical molecules in random motion in the mathematical representation of an ideal gas. This is theoretically a special limiting case, and empirically a state of affairs found only in regions of low density, at high temperatures or low pressures. There is a great deal of gas in the universe, for example in the spaces between stars, but the more interesting and the theoretically more important fact today is the hierarchical ordering. If the universe were nothing but gas, there would be no crystals, no organisms, and no solar systems or structured galaxies. It would be a bleak universe all on one level, without order, form, life, or mind. For everything 'formed' of parts has at least two levels: the form of the whole, and the parts.

The universe is not like an ideal gas. Large portions of it are highly ordered as a system of sub-systems each of which can in some respect be treated as an ordered unit. In my view this is the most general known fact about this unique universe. The paramount characteristic of nature is its hierarchical ordering. Only in the last few decades have pioneer thinkers begun to realize how fundamental this is, and to see the new vistas which it opens up. For it implies that our conception of physical causality, that is of the general form of the laws of nature, has to be reconsidered. We may have to learn to think of paired levels as fundamental in physics, cosmology, and biophysics.

Some of these vistas are easy for laymen to appreciate, because natural hierarchies are set in ordinary human three-dimensional space, not in the abstract hyper-spaces of mathematics. I shall take a striking example first: the 'top' level of the inorganic hierarchy, the largest system of all - the known universe.

Cosmologists believe (though a better interpretation may one day be found) that the entire universe, the vast world of galaxies, is expanding as a whole according to a simple numerical law. One must be careful here; the term 'expanding' can mislead, for it is empty and ambiguous unless some particular standard of length is specified. Actually the universe is expanding relatively to the size of the atoms or molecules which emit light, and these, I believe, are fairly near the 'bottom' of the structural hierarchy, i.e. near the smallest units, though this is an unorthodox view. So in this respect the entire universe is a well-ordered unit and must have been so for a very long time. Moreover this global ordering is not a property isolable at the top level, which would be meaningless, but is essentially linked to the 'low' level of the atoms. 'Expansion', properly understood, is a two-level property or ratio best expressed in dimensionless numbers, like angles or ratios of lengths. The process of measurement often consists in a comparison of levels.

Thus cosmological observations seem to be telling us that an important class of physical laws are those which link pairs of levels in the structural hierarchy. For an overriding global law linking cosmos and atom has determined this aspect of the history of the cosmos over the period of time covered by this general expansion.

The possibility of numerical relations existing between cosmos and atom has been recognized for some time. Now we can go a step further: the most general physical laws awaiting discovery may be dimensionless equations linking pairs of levels in the inorganic hierarchy. This is not mere speculation, for physical theory has reached a point of uncertainty when disciplined conjectures of this kind can

call attention to new problems and suggest methods for their solution. Moreover, dimensionless relations of this kind have been proposed by cosmologists during the last twenty years.

But that does not exhaust the interest of the top level. The discovery of this law of global expansion of the universe suggests that we may be reaching the frontiers of quantitative knowledge as now conceived in terms of distances, times, and masses. For the relation atom/cosmos in my view spans everything, and any numerical relation linking atom and universe must affect everything in between. Any interpretation of this expansion law must condition the whole of physics. A global law of the inorganic hierarchy must in some degree affect all its levels.

For those interested in the structure of physical theories this is a fascinating situation. Physics has given birth to a supposedly special branch: cosmology, or the physics of the cosmos. But it has turned out that cosmology, properly understood, is not a special branch, but should be viewed as the history of the whole process, including all physics. Atom and cosmos are inseparable, because they are two related levels of a single hierarchy which we can only fully understand by considering its global history. Perhaps a truly comprehensive physics must be quasi-historical, in the sense of representing one-way processes or tendencies. The history of the whole process and the local processes of parts may both display tendencies. If so, this is a cosmos of tendencies.

Now a glance at the inorganic hierarchy as a whole. If we start with the earth and pass to larger systems, there is the solar system, which is part of a galaxy, and the galaxies are not scattered at random but are grouped into clusters, and these again into super-clusters, the largest units in the known universe. Then if we pass from the earth to smaller systems, there are crystals, molecules, atoms, atomic nuclei, parts of nuclei, and a multitude of field-particles, which may turn out to be resonance states, or deformations, of systems composed of some ultimate particle. This is not an exact or a complete description. It is simply what one would see if one took an innocent first look — as it were — at the universe as a whole.

Do you share my awe in contemplating this grand ordering of the whole as a system of systems? It is similar to the periodic system of the chemical elements before it was understood: a complex but unmistakably ordered pattern clearly holding the clue to a deepened understanding of the world. My father would have seen in it the finger of God. I hear the universe saying: A universal order-generating process has created many forms of spatial order of different sizes, which over thresholds lapse into entropic disorder.

For two major tendencies are at work in the universe: one toward dynamical disorder (entropy) and one toward 3D geometrical order, which I have named the 'morphic' tendency. [1] These two cosmic tendencies, the entropic and the morphic, are so comprehensive that one may assume that together they cover every conceivable type of spatial process of interest to science. (Cyclic or reversible processes can be treated as limit cases of morphic processes.) On this view everything that happens in space must fall under one, or the other, or both together. The two are certainly not exact opposites, for morphic processes are geometrical and monotonic, while entropy processes are mechanical (in the sense of dimensional analysis) and are accompanied by fluctuations.

The entropy tendency has been studied for a hundred years, while the morphic has only recently begun to attract the systematic attention due to so far-reaching a class of processes. Indeed the occurrence of morphic processes at many levels of structure, and their consequent theoretical importance, was one of the characteristic blind spots of the dominant school of thought during the period 1860 to 1960. (This neglect was partly due to the fact that morphic processes are so badly brought up as not to occur in the 'closed' systems which were then regarded as the only ones worthy of the attention of serious physicists.) In 1944 Schrodinger introduced the term 'neg-entropy' for local order-generating processes, but he confused the issue in two respects. 1) He assumed without argument that processes generating biological order are the exact opposite of entropy processes. This is almost certainly wrong. Biological order is not the opposite of thermal disorder. 2) He did not point out that order-generating processes occur at every level of the inorganic and of the organic hierarchies. This means that there are some ten to twenty morphic processes, according to the method of classification used. Only the systematic study of structural hierarchies forces one to realize the existence of so many morphic processes. This fact is now slowly becoming obvious.

I have called this a recent blind spot. Of course some were not blind. For example, in 1930 Harlow Shapley published a book, Flights from Chaos, in which he listed fifteen levels of ordered structures and processes from cosmos to ultimate particle. This provokes the question: In how many

of Shapley's levels has the morphic process which generates the level already been identified and its laws discovered? Today the answer is far from obvious, because it is at the frontier of knowledge; in a generation every keen schoolboy will know it.

Notice that morphic processes generate levels, while entropic processes disperse them. But in most cases we do not yet know the morphic conditions (of pressure, temperature, etc.) that determine (i) which tendency wins in some selected region of space at some particular level, and (ii) when they cooperate, as in organisms.

Most physical scientists can be classified by the level of their main interests: as cosmologists, astronomers, geologists, crystallographers, chemists, and atomic or nuclear physicists. Some manage to watch two or three levels, and we might use the XVIIth Century term hierarchist for scientists actively studying the relationships of several levels. I hereby grant the title of Hierarchist Number One to Linus Pauling, for he has made important contributions on four or five levels.

But I have not yet mentioned the most remarkable achievement of the inorganic hierarchy: it has given birth to life, though living systems display a very different kind of hierarchical structure! The inorganic has on this planet produced a new realm of hierarchical systems: the myriads of highly contrasted mini-hierarchies, each linked to a favorable environment, which we call organisms. This is an awe-inspiring fact: on at least one planet in the great inorganic life has come to life!

This emergence of evolving life within so contrasted a background opens up mathematical, physical, and biophysical problems as yet barely formulated, let alone solved. Many of these are contained in this master question:

ARE THE BASIC LAWS OF PHYSICS, THE LAWS OF THE INORGANIC HIERARCHY, LOGICALLY RICH ENOUGH TO ACCOUNT FOR THE EMERGENCE OF ORGANISMS CAPABLE OF EVOLUTION?

I mean, of course, without supernatural intervention, divine or devilish. If any scientist answers unconditionally Yes, or No, he is displaying what I must have the courage to call grossly unscientific dogmatism. For the simple fact, which should today be obvious to any unprejudiced scientist, is that we do not know enough about either the inorganic or the organic realms to decide what is their precise relation. We have as yet no unified theory of physics and no general theory of the inorganic hierarchy. Nor have we a valid theory of organism; as yet we have not even identified the hierarchical coordination which gives organisms their characteristic properties. Anyone who pretends the contrary is suffering from that already mentioned professional malady of scientists: to exaggerate what is known, and should be given treatment so that he does not forget that unconscious assumptions lurk in all unconditional generalizations.

I cannot here analyse the contrast between inorganic and organic structural hierarchies. Organisms are inseparable from their environment, are heterogeneous, display continuing structural pulsations and metabolism leading to replication and reproduction, and in many cases organic units appear to impose constraints on the degrees of freedom of their parts. The inorganic hierarchy does not in general, or so markedly, display these features. Thus the inorganic appears to possess more restricted properties than the organic. Yet the inorganic has produced the organic; the apparently poorer has given birth to the richer! What kind of logical misbehavior is this?

The clue lies in the fact that this antithesis is misleading. The crucial question is rather: Can organic hierarchical coordination be shown to be a special case arising from the application of the most general physical laws to an increasingly complex sequence of systems? Or better: Can the physical laws account for the emergence and progressive evolution of increasingly complex hierarchical systems with the properties of organisms? We do not yet know enough to answer this question.

But there may not be very long to wait, for this is the preparatory decade of hierarchy, as is indicated by the following facts:

A. The quantitative relations of structural levels are now being actively explored in three realms: in the classification of elementary particles, in cosmology and the links between atoms and galaxies, and in biophysics, e.g. the levels of primary to quaternary structure in proteins, and nucleic acids. [2] All this began around 1950/60.

B. During the 1960's at least a dozen significan papers [3] have been published on the philosophy of physical and biological structural levels. This is unprecedented.

C. The first two international conferences [4] in the history of science on the scientific problems of hierarchy (one on levels in physics, cosmology, computer operation, and biology; the other on reductionism and hierarchy in psychology, sociology,

and linguistics) were held in 1968.

However this heightened attention to levels of structure during the 1960's does not imply that the advance from current theories to a theory of hierarchy will be easy. For the transformation required for this advance touches many difficult theoretical problems, of which I will only mention two.

1. In Einstein's Special and General Theories of Relativity, it is assumed that in a fundamental analysis temporal relations cannot be separated from spatial relations. I believe this cannot apply in a theory of hierarchical levels of spatial structure, in which spatial relations and their changes in course of time must play a primary role, quantitative temporal relations being secondary and derivable from changes in spatial relations. If so, a radical change is necessary, but fortunately one towards the immediacy of 3-D space, as against the abstract higher spaces of relativity and quantum theory.

2. Since 1890 many scientific theories and philosophical concepts, expressing a reaction from the extreme analytic-atomic ideas of the late XIXth Century, have stressed the importance of global properties and parameters, i.e. those associated with the totality of a system. The most important of these are: Gestalt Theory (psychology); Emergent Evolution, Organicism, and Integrative Levels (biology); Symmetry Theory (crystallography, quantum theory); cooperative processes (physics), field effects (embryology), and unitization (information theory). Lying behind these ideas and common to them all, lies one basic principle: the quantitative laws which some systems obey are best expressed, not in localizable atomic or field parameters associated with particles or points, but in global system variables (such as deformations from symmetry).

For example, a principle of wide scope might be: 'A deformed system relaxes by a one-way process towards a terminal equilibrium state of higher order or symmetry.' [5] If this principle is applied at several levels of an organic structural hierarchy we reach the conception that in organic hierarchical systems a sequence of morphic processes occurs at several levels. This may appear to be a rather new idea. But it is not. For in 1912 N. Hartmann [6] suggested that in organisms there is a hierarchical sequence of formative processes. But at that time the importance of this penetrating observation was not appreciated. It was fifty years too early.

The advance from a collection of separate laws of invariance (conservation, symmetry) to a hierarchy of morphic processes requires a radical intellectual adjustment. Yet the intellectual pressure in this direction is already considerable, and it would be rash to exclude the possibility of steps being achieved soon.

This is all I have to say now about the view from one frontier of exact science. If these conjectures are broadly valid, how do they affect our conception of what it means to be human? I suggested at the start that to understand hierarchy is one way of understanding ourselves. Here I have only one observation to make, but it is far-reaching: A theory of organic hierarchy necessarily contains organic values which are powerfully at work in man as organic tendencies, even when he is unaware of them.

A theory of organic structural levels treats a highly coordinated sequence of types of ordering. An organism is a system which, when not pathological, tends to promote characteristic orderings at several correlated levels. Organic ordering has internal and adaptive value for organisms. This means that the separation of fact and value in recent academic philosophy vanishes in a hierarchical theory of organisms. Organic value is present in the objective representation of organic facts. Value plays an inescapable part in any theory of organism, and organic coordination necessarily possesses value for reflective organisms. Thereby the supposed 'objective' in the sense of neutral 'science of man' does not exist. The movement towards this supposed science transforms science into something more than science.

In fact, homo sapiens can never experience 'life in an age of science'. The past (since 1600) and the present (1960's) are both marked by the absence of a balanced and comprehensive science. The future (say around 2000 AD, for it cannot be many generations ahead) will, I believe, be characterized by a doctrine containing values which therefore goes beyond 'science' in the strict traditional sense. We are now most unhappily in the transition from a less than scientific past towards the dawn of a more than scientific future.

CONCLUSION

Has my description of one frontier of science been broadly valid or not? No one can say today. Ideas may be interesting and yet mistaken.

So I invite the Institute to join me in an historical experiment of a kind which may never previously have been attempted in the history of scientific theory.

In a period of convergence, when it is reasonable to expect better unified theories, for example of the field-particles of physics, ten thinkers may anticipate in general terms the kind of ideas which are necessary for the one who achieves the definitive clarification. Do I qualify as one of those ten?

My suggestion is that the Institute of General Semantics serve both as historical witness and as judge, and report to its members in 1979 whether my attempt to peer through the fog of our ignorance has turned out successful or not. The following paragraph puts on record my prediction:

I expect that by 1979 a major advance in fundamental physical theory, in the quantum theory of electromagnetism, will have been made which:

(i) Explicitly treats the relations of hierarchically paired levels of structure in physical theory.

(ii) Identifies one such pair as follows:

(a) A spatially more extended level covering electrons and photons.

(b) A more stably localized level covering protons.

(iii) Uses 3-dimensional geometrical relations as primary in the theory of hierarchical systems, and treats temporal relations as secondary.

So help me physics!

FOOTNOTES

1. See 'Organic Structural Hierarchies,' essay in Bertalanffy Festschrift 'Unity and Diversity in Systems,' R.G. Jones and G. Brantl, editors, Braziller, New York. This volume also contains an essay by A. Koestler on hierarchical problems. (See also note 4a below.)

2. For an interesting example of recent work throwing light on Secondary and Tertiary Structure in t.RNA, see F. Cramer, et.al., Proc. Nat. Acad. Sci., 61, December 1968, pp. 1384/91.

3. For full bibliography on structural hierarchies see note 4a below.

4. Volumes reporting these conferences will appear 1969/70:

   a. Hierarchy and Levels of Structure, A.G. and D. Wilson and L.L. Whyte, editors. Contains full bibliography. Information from Professor A.G. Wilson, Douglas Aircraft Advanced Laboratories, 5251 Bolsa Avenue, Huntington Beach, California 92647.

   b. Beyond Reductionism, A. Koestler, editor, Hutchinson, London.

5. This has been named the 'Unitary Principle.' See The Unitary Principle in Physics and Biology, L.L. Whyte, Holt, New York, 1949.

6. N. Hartmann. Philosophische Grundfragen der Biologie, Göttingen, 1912.