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THE NEED FOR GENERALIZATION IN BIOLOGICAL RESEARCH:

ROLE OF THE MATHEMATICAL THEORY OF ENSEMBLES

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Dear Friends: I am at a loss to express to you how honored I feel to be giving this lecture, and to find myself at this gathering dominated by the great figure of Alfred Korzybski. I did not have the joy of knowing him personally as did some others here, most particularly M. Kendig, who continues his thought and perpetuates his presence among us. However, his thought is written in books, and through them, I believe I can call myself one of his disciples. Although the following exposition does not make frequent reference to his name as it should, this is not a necessity for you to understand that I wrote it to honor his memory and to participate, however modestly, in the continuation of his thought.

If we wish to avoid getting lost in the complexity of living phenomena, it would be well, first of all, to agree on some very general notions. We shall turn to the 'Theory of Ensembles' (or Sets) for a methodology. From the 'Universe' taken as an ensemble, man abstracts those elements that he is aware of through his senses. This awareness seems to be limited to the abstracting of discontinuous elements. His knowledge as far as it concerns <u>action</u> is limited to the <u>quantum</u>, and as far as it concerns <u>mass</u>, to <u>elementary particles.</u> We tend to share with our friend Jean Charon the opinion that these two forms constitute the elements of the <u>Known</u> -- whereas one can validly think of the <u>Real</u> as being continuous.*

THE NOTION OF 'STRUCTURE'. ANIMATE versus INANIMATE

Living organisms are made of the same matter, the same elementary particles, as inanimate objects. We can therefore assume that their specific characteristics derive from a particular <u>Structure</u>. This word 'structure' immediately calls for a definition. From a very general point of view we shall define structure as <u>the totality of relationships existing among the elements of an ensemble</u>. Thus, in the living organism, structures will characterize the relationships of the elements among themselves, and the relationships between sub-ensembles and their parts. Structures will therefore characterize <u>levels of organization.</u>

These relationships can be demonstrated at the sub-molecular, molecular, and intracellular levels of organization (nucleus, mitochondria, microsomes, etc.), in fact at all levels of complexity of biochemical processes whose regulated functioning is the basis of cell <u>metabolism</u>. We must grasp the dynamism of these relationships, that is precisely clarify their energetic significance. Energy phenomena at this level of organization can be apprehended in its physical aspect or its chemical aspect and life appears to be the consequence of the regulation of electronic exchanges, regulation in which free radical forms, electro-magnetic resonance and migration of excitons, play a dominant role.

*See General Semantics Bulletin, Numbers 28 & 29, 'Toward Understanding the Universe' by Jean Charon, 4-11.

ROLE OF INVESTIGATION TOOLS

The electron microscope will yield one particular aspect of structure, and sometimes of its variations in relation to normal or physiological function and to abnormal or physiopathological function. But the investigation of dynamic phenomena will require the study of enzyme reactions, all the technical resources of enzymology and the use for example of molecular tracers. Thus from the most simple stages of organization of living structures, we must have as our essential goal joining the static to the dynamic, i.e. the morphology to the function.

Due to the limited means of investigation that were available in the last century, the basic unit of organization of complex organisms is still in our days 'the cell' following the concept introduced by SCHWANN. It seems that with the improvement of our techniques and the resulting increase in knowledge, we should soon be able to move to a deeper level of organization and look for this basic unity in the nucleus, and probably more precisely in the desoxyribonucleic acid molecule. The morphological structure of this molecule is now known, and its energy dynamics are becoming progressively clearer.

Thus elementary particles, participating in the formation of molecules, themselves gathered either into intracellular organites, or constituting the endoplasm, separated by a membrane from the less complex surrounding medium or extracellular environment, are capable of forming a cell only because of the particular relationships that exist among them. These relationships provide the cellular structures under their two forms: morphological and energetic.

It becomes clear that in order to acquire this knowledge, the fundamental sciences are physics and chemistry, or better still physical-chemistry combined into a particular structure, i.e. a biological structure. Physical-chemistry will be as much needed for the application or the discovery of techniques of observation as for the understanding of the particular dynamic forces which activate elementary particles in cellular metabolism. Thus, physical-chemistry will be required not only for techniques of electron microscopy, but also for spectrography, gas phase chromatography, electrophoresis and electron spin resonance (ESR), as well as for the recording of intracellular potentials with microelectrodes, the use of tagged ions and molecules, to name only a few of the techniques which have made it possible, little by little, to describe the relationships existing between metabolism and cellular function, in other words, better describe certain cellular structures. Solid state and semi-conductor physics have recently shown similarities between protein molecules and crystals; and have utilized knowledge acquired in the inanimate realm for enriching our knowledge of life.

THE BASIC UNIT versus ITS ENVIRONMENT

But the internal dynamics of the basic unit, the cell, would be of little interest if it were not placed within its general context, i.e. its immediate and mediate environment in space-time.

The immediate environment is the inanimate medium which surrounds the cell, and from which it is separated by its membrane.

We cannot conceive of the preservation of the structure of a living organism in a surrounding medium unless there exists a continuous exchange of matter, i.e. energy, between them. This exchange takes place in only one direction, that leading toward maximum entropy, according to the second principle of thermodynamics of CARNOT-CLAUSIUS, and, at our level of observation, in keeping with a specific rate-reducing mechanism without which life would be nothing but simple combustion. The presence and maintenance, thanks to a continued 'turn-over', of highly differentiated structures in the various species and in the living individual implies the existence of special regulatory mechanisms operating between these structures and their environment. We believe that the cybernetic methodology is indispensable for gaining an understanding of these regulatory mechanisms. This will enable us to understand how, through feed-back, the effect of an effector keeps the value of the variable factors which determine it within certain limits, thus forming a regulatory system. Cybernetics will also explain how the action of a variable factor extraneous to the factor-effector-effects system on this feed-back loop converts this regulator into a servomechanism; and how most often this servomechanism creates a relationship between two different levels of organization, thus allowing for the creation within structures of relationships between functions. This type of regulation by servomechanism is to be found at each level of organization of living matter, from the protein molecule on up through the most complex organisms, to MAN. Furthermore, such regulation determines Man's psychobiological behavior in his environment.

When we reach the highest level of organization of living matter, we observe that the existence, the growth, the maintenance, or the death of animal or human societies - and this observation applies also to Humanity within the cosmos - are subjected to such regulations, and that sociology and political economy are primarily biological problems. A mitochondrion, for example, can maintain its integrity only as long as the cell structure to which it belongs also maintains its integrity; this integrity in turn is dependent on the maintenance of the integrity of the organ, which in turn depends upon that of the organism within its environment; similarly, each human group can preserve its structure only if the group is part of a more complex structure, i.e. one with a higher level of organization. On the group depends the existence of this more complex structure, on which, in turn, the existence of the group depends.

ENERGY AND LIFE

Now the maintenance of living structures is essentially the consequence of the flow of currents of energy through them and through the open systems that they form. As that current flows through these structures, energy is degraded (increasing entropy) and this phenomenon shows that biological phenomena indeed follow the CARNOT-CLAUSIUS principle. The understanding of the life-phenomena under its thermodynamic aspect is a critical example of the need for generalization in biology. In our opinion, it is impossible to understand anything in sociology and political economy, in the dynamics of human groups, in human physiology and pathology, in zoology or in any of the ancillary disciplines (which is to say briefly, in the biological sciences as a whole) if these sciences are not placed within their cosmic thermodynamic context - if we do not remember constantly that these living structures, studied by these sciences at various organization levels, owe their existence to the supply on this earth of solar photonic energy. Consequently there is perhaps nothing more important to know in life sciences than the mechanism of chlorophyll photosynthesis.

This mechanism shows how the excitation of the chlorophyll molecule, that is to say, the transfer of one of its electrons to a more peripheral orbit, makes possible the accumulation of the photonic energy of the sun in this excited electron. This photonic energy can then convert into chemical energy in the form of energy-rich phosphate bonds (adenosine tri-phosphate, ATP) and bind the hydrogen molecule taken from water into complex organic molecules such as carbohydrates, lipids, and proteins. Whatever is alive on earth derives the energy for the maintenance of its structure from this universal source. Obviously it would be too tedious to review this notion even superficially and to demonstrate that human societies, just as bacteria, exist and regulate themselves with respect to their environments, thanks only to the enormous flow of converted solar photonic energy through their structures. At the least, we can insist that nothing is more important to biology than the generalization of this thermodynamic notion, since finally this solar photonic energy will as it leaves living organisms be degraded into heat, after having in passing done a tremendous amount of work, of which the human psyche is only one form.

ENTROPY AND LIFE

The solar photonic energy, by the molecular excitation it generates, will facilitate the synthesis of complex molecules. In temporarily promoting disorder, an increase in entropy, this energy will secondarily promote order. In other words, by increasing temporarily electron agitation (quantum jump), this energy will secondarily increase the degree of organization of matter.

If we consider that atoms A and B, in uniting, are capable of forming the sub-ensemble of molecule E, then, by this union, solar energy will have made possible the creation of an 'intersection', or a new ensemble D, since its elements (the electrons) belong to both A and B. In biology, the delocalized π electrons of some organic molecules are of fundamental importance, possibly because these electrons facilitate 'intersections'. The covalent or heterovalent bonds, and the conduction bands of large protein molecules also form intersections. The intersections of biological molecules, in our opinion, are characterized by their lability. This is why we have suggested the name 'intersectates' for those electron intersections which can exist only if a constant supply of energy (whose origin obviously can be traced back to solar photonic energy through chlorophyll photosynthesis and the resulting formation of organic molecules) maintains the excitation state responsible for their existence. A semi-conductor crystal does not lose its structure if the flow of current passing through it is shut off. But a semi-conductor living molecule loses its structure and its properties if the energy supply originating from ATP does not constantly flow through it.

FINALITY AND LIFE

Here lies the difference between the most complex machine that Man can make and the living machine. The purpose of a copper wire in an electronic circuit may be to conduct current. If it is separated from the electrical energy source, it nonetheless remains a copper wire. Its structure does not disappear with the loss of its finality (purpose). On the other hand, a living organism that does not fulfill its finality dies. Its structure disappears with the disappearance of this fulfillment. From this evident consideration, we shall draw three conclusions:

1. The finality of a living structure is the maintenance of this structure, of this stable state.

2. The maintenance of the structure is a finality that will be found at all organization levels of life, from the simple molecule to Man.

3. Each specific activity of a sub-molecular, molecular, mitochondrial, microsomal, nuclear, or cytoplasmic structure, as well as each specific activity of a cell, of a tissue or a system, of an organ, is aimed at the maintenance of the structure of the element considered vis-a-vis its immediate environment and the physico-chemical condition of which will be controlled by feedback. This is the only possible 'means' for the maintenance of the structure of the whole organism within its own environment.

THE PERMANENCE OF STRUCTURES vs. FACTS

Physical-chemistry in its most varied aspects - electronics, thermodynamics, solid state physics, inorganic and organic chemistry, biochemistry and enzymology - is therefore necessary for biological research. In order to understand the dynamics of the ensemble, the methodology of cybernetics and modern mathematics, particularly with the theory of ensembles which they offer, are equally necessary. And yet all this will take us barely beyond the degree of organization of the cell.

It can be understood how much physiology was handicapped until recent years without this fundamental knowledge. Without this knowledge, how would it be possible to grasp and interpret - that is to say, to control and use to the best advantage of human needs - the functioning of subjacent levels of organization, such as the functioning of organs and systems (nervous, autonomic, endocrine, reticulo-endothelial, etc.). The active mechanism of hormones and neuro-hormones, the chemical mediators of nervous influx, would be incomprehensible. Of course, painstaking analytical studies and accumulation of facts were indispensable. But the number of facts, that is the elements abstracted by our senses, in the sub-ensemble 'life' within the ensemble 'Universe' is practically unlimited. It depends upon the number of observers, upon the conditions and facilities of observations, and since facts do not exist in the absolute, but exist in a space-time continuum, they can never remain the same, since matter is a mixture of space and time.

<u>What remains is not the facts but the structures.</u> When serious investigators state that they believe only in observed facts (which they often do), they commit a grave semantic error. They mean to say that they believe only in structures, in stable (one might even say eternal) relationships between facts which are evanescent, changing, uncertain, 'sensory'. Facts are valuable only because they lead us to structures, to what scientists call 'laws'. We can be <u>sure</u> of the existence of these structures since in spite of the variability of the factors which condition the multiplicity of these never identical facts, the structures remain. We are also certain, however, never to be able to abstract the ensemble of relationships unless a unitary theory is discovered from which these relationships will all derive. In other words, probably we shall have to be satisfied for a long time with a sub-ensemble of relationships existing among the elements we perceive.

DESCRIPTION versus UNDERSTANDING OF LIFE

Until recently, the poverty of our means of investigating Life at the level of its atomic and molecular structures limited basic biological sciences to the microscopic and macroscopic levels of observation in histology, anatomy and general physiology. This level of organization was explored during the past century in all living forms. If the knowledge of the existence of microbes belongs to the era of PASTEUR, that of viruses, unquestionably suspected by him, is contemporary. But even today structures are not taught; i.e. the relations between the micro- and macro-scopic levels and those under- and over-lying them are rarely described. Physiology and physiopathology are discussed in chapters dealing with individual organs separately, and it is not unusual to find physiology textbooks beginning with the study of the internal environment, of the blood, of blood groups and coagulation, rather than with the study of structures. It is even more usual to find pathology textbooks which begin with what is called 'general pathology', i.e. the pathology of tissues and the main syndromes such as shock, burns, infections, etc., which are already only sub-ensembles of pathology. None of these textbooks places the living organism in its energy context and shows it undergoing the effects of quantitative changes of energy supply (intensity x time). In our opinion, however, this notion is the basis of the whole of acute pathology (when the intensity of the stress assumes a greater role than its duration) and chronic pathology (when duration is more important than the intensity).

Physiology and physiopathology are still limited most often to description without explanation. An explanation could arise only from the discovery of structures, of the relationships existing among observations collected at various levels of organization. What is happening now in physiopathology is analogous to what took place some years ago when physical chemistry had not come of age and the subject of chemical valence was taught to students as the presence of a + or – attached to a chemical symbol without it being said that this meant the presence or the absence of a negative charge, an electron, on the external orbit of an atom. (In other words it was not yet physical chemistry.) From the same molecule E, a chemist, a physicist and a biologist, for instance, will abstract different elements, and for each scientist these elements will constitute the molecule E, whereas actually they form only a sub-ensemble. The unification and intersection of these sub-ensembles will provide better, although still incomplete, knowledge of this molecule E. However, it still remains to describe the relations of this molecule E with other molecules which surround it and then the relations of the new structures thus created with adjacent levels of organization.

The same search for structures is necessary in physiology and in physiopathology. For instance, a psychiatrist who studies the disturbances of the human mind must first locate them within its animate and inanimate environment, i.e. its social and geo-climatic environment. Then he must study what we may call its neurological aspect, the relationship of neural groups among themselves. He will extend this study by investigating the relationships of the nervous system with the myriad of other structures which form a complex organism; then he will consider its metabolic and physical-chemical substrate: this will lead him to sub-molecular biology. At no time should he lose sight of the necessity of bringing into light the normal or disturbed relationships existing among these various organization levels. This is the work of generalization.

GENERALIZATION: A DEFINITION

We should now perhaps attempt to explain, however awkwardly, what we mean by generalization. Using the terminology of the theory of ensembles, we feel justified in saying that 'to generalize is to create new ensembles or relationships encompassing a certain number of ensembles whose basic characteristics have already been defined.'

EVOLUTION OF LIFE

Before going any further, we must draw attention to another essential notion. At present, life on our globe has manifested itself through numerous and different forms which nevertheless show obvious structural analogies. Everything leads us to believe that the most complex structures that can be observed in our days are the results of long evolution, and it is essential that the biologist try to know what the most elementary forms of life at its beginning were like, as well as what relationships existed in the past among the early forms and those that followed. The diverse forms taken in the course of the early periods by photosynthesis, forms still in existence today, show definitely increasing complexity. Thus ARNON has described a cyclic type of photosynthesis which existed when hydrogen was still plentiful and oxygen scarce in the earth's atmosphere, and a non-cyclical photosynthesis which led to chlorophyll photosynthesis in which the hydrogen donor is water, and which was the origin of the accumulation of oxygen in the earth's atmosphere.

We would like now to take the liberty of presenting a hypothesis, however fragile it may sound, in order to demonstrate how a generalization may be at the origin of a new working hypothesis which might turn out to be fruitful.

As a consequence of what we have just stated, it is possible that oxygen is not required for life, since life most likely appeared in an earth atmosphere then deprived of oxygen, and since at the present, certain 'anaerobic' organisms do without it. But the fermentation processes from which they draw their energy can synthesize only two ATP molecules from one glucose molecule, whereas under aerobic conditions, when the electron acceptor is oxygen, 38 molecules of ATP are synthesized from one glucose molecule. Now ATP is an immediately usable energy source for life, not only to maintain its various structures, but above all to furnish mechanical work. It is thanks to this mechanical work that life will be able to act on its inanimate environment by modifying it to best advantage for its own survival.

Thus molecular oxygen, a double radical, in spite of its definite toxicity, provides life with a neat and perfected means to act on the environment instead of ceding entirely to its demands. Oxygen, therefore, has made evolution possible. This brings us to the now familiar understanding - since it is at the origin of artificial hibernation - that the preservation of life and of the freedom of motion are two different things. It follows that life can often be better protected by suppressing this freedom of motion. It should be recognized, however, that when geographical and climatic conditions became stable on earth, the forms possessing freedom of motion became each other's worst enemies. Then this freedom of motion which permitted both flight and fight, and finally homeothermia, which made motor activity possible during the winter months, became the best guarantee for the evolution and success of the higher vertebrates and of Man. This freedom of motion is dependent on the plentiful synthesis of ATP because oxygen can take up electrons in the course of phosphorylant oxidation. But oxygen is also responsible for the oxidation of membrane lipids leading to the formation of lipoperoxides which interfere with the physico-chemical structure and the permeability of membranes, interfering with exchanges between living structures and their environment. In our opinion, this is the basic cause of aging which appears then as resulting from life in its most perfected oxidative form.

This leads, therefore, to the following perhaps only temporary dilemna, that a type of life as perfected as ours needs oxidative processes without which it probably would not have appeared, but that these processes are probably at the origin of aging and death. Eternal life with submission to the environment, or freedom with death are then the two alternatives. Aging and death are actually inherent to individuals but not to life. As far as life is concerned, death is useless and not comprehensible; but without death, evolution cannot take place. Life could have continued as it appeared in its simplest form. For an individual, on the contrary, death is the secret of evolution toward more and more complex forms, through the return of material to the common pool of organic substances and their slow evolutionary reconstruction through the ages, as long as solar energy makes it possible. Here, again, the notion of structure outweighs the value of energy. One man of genius can have more control over the inanimate world than the plankton of all the oceans.

COMPLEXITY OF STRUCTURES & EVOLUTION

This notion leads us to consider that if entropy is an expression of disorder, the appearance of more and more complex forms of life, progressively stored with more information and better organized, is a form of negative entropy. On the physico-chemical level, it seems hard to achieve something more complex than a nucleoprotein. The higher degree of 'complexity' of the human organism, when compared to a virus, is neither the result of a higher degree of organization of its molecules taken separately, nor their larger number. It is the result of the higher degree of organization of these molecules among themselves into systems within different hierarchical organization levels, submicroscopic, microscopic, macroscopic. Each of these levels is connected with and influences all the others. Finally the ensemble as a whole has an influence on each of these levels. It is, therefore, the structure that is more complex.

Is there perhaps no more life in our world today than there was on its first days? But life has certainly become more complex and since its manifestations have grown more and more organized, are stored with more and more information, it can doubtless be said on that basis that there has been an increase in negative entropy.

SEARCH FOR STRUCTURES & GENERALIZATION

How could it be possible to keep within tight boundaries the innumerable disciplines to which the biologist must have recourse to grasp the phenomenon of life? The search for structures by means of the intersection of different disciplines presents, however, some drawbacks. In view of the fact that until now the orientation toward analysis has dominated the evolution of biological sciences, leading to a considerable degree of specialization of investigators, the generalist, however efficient his methodology, will meet with the inability of the scientific world to understand the significance of this search for structures which it will regard as a contemptible 'metaphysics'. A few years later, once the environment has matured, the generalist will be faced with the possible reappearance, under a different name, of the syntheses he had offered earlier to a milieu not yet ready to receive them. His only hope is, on the basis of yet unaccepted generalizations, to try to bring about new observations that may have a chance to be accepted as such, since they are divorced from their structural context. The organic synthesis approach to pharmacology is an example of what we are saying.

Nevertheless, we believe that we have offered enough arguments to show that the search for structures, made possible only through generalization, is undoubtedly the research method the most likely to lead to the discovery of laws as well as of new facts. Some disciplines, valuable in themselves, such as theoretical physics, require little more than a sheet of paper and a pencil as working tools. True, experimentation, often highly specialized, remains indispensable. When in biology, for instance, we have freed ourselves from the semantic mistake of believing that our so-called 'defense mechanisms' protect our life when they only guarantee our freedom of motion, then it is a specialized work to synthesize compounds that can, at all levels of organization, decrease molecular excitation and orient the metabolism toward the storage of hydrogen molecules instead of the liberation of the energy of its electrons in phosphorylant oxidation processes. But it is a much less empirical and costly method than the one consisting of the synthesis, without general hypotheses, of thousands of new compounds, hastily and blindly tested on laboratory animals, then introduced in therapy.

The pharmaceutical industry has thus often forgotten that its purpose is to assist in the improvement of Man's condition and not basically to sell chemical products to improve sales figures. In their ignorance of general concepts, and on the basis of restricted relationships, organic chemists have empirically complicated chemical structures instead of simplifying them. We must not forget that pharmacological synthesis is just about the only biological discipline that is commercially profitable. Consequently, in many countries, so-called 'fundamental' research will meet with great difficulties in finding the investments necessary for its development. And yet it is this fundamental research which, in the long run, has the best chance of becoming, even commercially, the most profitable. But even if it were not so, the evolution of humanity, in our opinion, must be oriented not towards the production of consumer goods, by which we are beginning to be stifled, but towards the conquest of the Universe by Man. The non-commercializable capital of Humanity, the essential non-negotiable wealth is the Universe. When an organism has reached adulthood (Manhood of Humanity), it must use the energy it takes from the environment, not to increase its size and finally die from overweight, but to release an energy capable of modifying the environment to the best advantage of survival. The day of the merchant must end if we wish to see Homo Sapiens emerge.

RESEARCH AND RESEARCHERS

Before bringing to an end this discussion on generalization in biology, we would like to say a few words on research and researchers. The researchers' motivation, in our opinion, is the desire to understand better. It is curiosity, but of a general nature - a need to better understand Man's place and role in the Universe.

Such curiosity will condition an essential factor of research: the collection of information. Indeed, a problem may be approached in many ways. It is possible to multiply investigations within a limited conceptual framework, which requires a lot of money and many researchers, and complicated and abundant instruments. Or it is possible, on the basis of already known facts, to offer a working hypothesis to be checked by experimentation. The best solution, obviously, would be a combination of both methods.

The elaboration of a working hypothesis often calls on what is generally called Intuition. This is not a mythical figure related to the Muses or a special gift similar to the 'hunch' in mathematics. It is not quite an inborn gift. However, as it can be accepted that 99 percent of our past experience has become subconscious, although always present in our nervous system, in our opinion, intuition is the confidence granted to this now subconscious acquired experience. Whoever accepts only clear ideas, a working hypothesis based on conscious, logical, let us say cartesian reasoning, deprives himself of the enormous mass of information he has accumulated since childhood and that populates his subconsciousness. His experiments will explore only a limited number of possible solutions - those connected with his present state of consciousness - with his consciously available information. Thus we believe it behooves the researcher to let his 'sixth sense' guide him, with the knowledge that this guidance is probably no more than an integrated expression of the information that he has been able to acquire, and that constitutes the experimental capital acquired by his nervous system.

The consequence of such a conception is that one of the essential duties of a researcher is the search for, and storage of, information. He must, therefore, read a lot and emerge as often as possible out of his immediate environment to establish a broad contact with the most diverse scientific personalities and thought. Indeed, besides the quantity of information, its quality must be considered. A specialist who pays attention to scientific development only within the restricted field of his specialty has, in our opinion, only a slim chance to make a significant discovery. A significant discovery generally affects many aspects of human activities; it can be applied in many disciplines and opens new paths in various directions. If such a discovery often assumes the form of a law, it is because it most often deals with structures.

Whatever may be the discipline to which he belongs, the researcher must, therefore, gather information in other disciplines. The value of such information will reside above all in its variety. Whether he is a biologist or a psychopharmacologist, he will have to know that the philosophies, chemistry, more particularly physical-chemistry, are as useful to him as physiology, zoology, paleontology, comparative physiology, embryology, neurology, psychology and art in general - although this is by no means a restrictive list. A living phenomenon is a unique phenomenon which must in the end be approached in its ensemble, because it is we who, on account of our inability to grasp synthetic and dynamic organization, are responsible for the analytical and artificial study of its biochemical, bioelectrogenetic, physiological, physiopathological, etc., aspects.

A researcher must be, above all, a generalist. But in his search for structure his chief goal must still be to avoid confusing levels of organization; he must grasp the dynamic aspect of systems and try to determine the purpose of each, that is, the effect of its action.

May we now propose a distinction between the artist and the scientist, who often share a strikingly similar approach. We would say that the artist, like the scientist, restructures relationships among elements perceived in the external world; the scientist must also abstract unknown elements from the environment. Hence the importance of technology in the evolution of science - while the difference between cave painters and our contemporary artists is that the latter use ready-made colors in tubes.

RESEARCHERS AND RESEARCH TEAMS

Another principle concerning research and researchers deals with what is called 'team-work'. Obviously, an assembly of scientists belonging to various disciplines is not in itself a sufficient guarantee of the group's efficiency. Such a group can only be called a gathering. In this case, each individual, sharing no common principle with any of the others, will speak a language that only he understands. An efficient group, however, may be visualized as an ensemble, of which each individual represents a sub-ensemble. Each specialist must, therefore, share many elements in common with his colleagues. This can be achieved only if each specialist, while remaining perfectly informed in his own field and its progress, makes a daily effort to acquire information in disciplines other than his own. So defined, an efficient team is not a gathering of specialists, but rather represents an intersection of generalists.

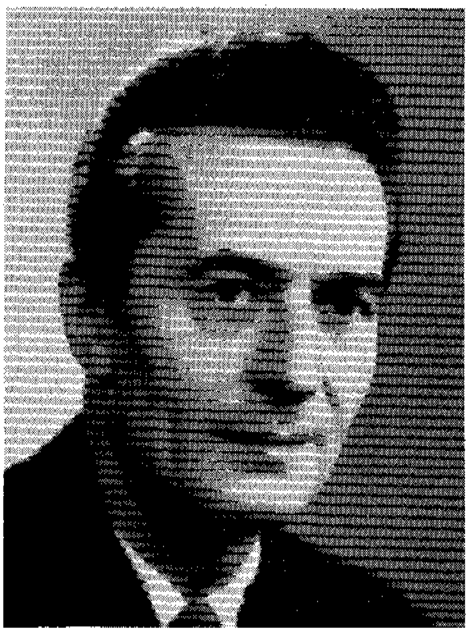
CONCLUSION

In view of the enormous breadth of learning which will be required of future researchers, if we wish them to be productive, they must be chosen early, prepared for their role, and surrounded by specialized technicians capable of supplying experimental confirmation of their hypotheses. These researchers must be young in spirit and remain so as long as possible, in order to avoid the semantic blockages of the aged. If antiquity reserved a privileged place to old, experienced, wise men, it is because the world did not then move at such an accelerated pace. The modern world risks stagnation if it permits itself to be governed not by men but by aging minds. Experience drawn from facts is only valuable for the present instant - which has already vanished -

if one does not retain from the past the structure of events which characterized it. In a constantly evolving environment, how can we seek 'identical' effects by duplicating what we believe to be 'identical' causes? This childish determinism no longer conforms with general relativity. What many men call experience and regard as the crowning virtue, is often nothing more than the sensing of a world which is already gone at the moment it exists.

It is actually the deep awareness in each of us of these continuous reciprocal adjustments among cosmic events, that must help us build the science and the world of tomorrow. Perhaps machines will aid us.

Finally, since we have scientific access only to the known - sensorily perceived and anthropomorphically distorted to our image - let us beware of talking of the real. What is there between the electron and its nucleus? Space-time? Are we not essentially made of such 'stuff', while our current biology is based on waves and particles? What does this non-material energy which constitutes most of our being have in store for us? What relation has it with our flesh and with the general texture of the Universe?



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(Continued from page 6)
to others for some time and had even been investigated in a tentative way, but it was Dr. Laborit who recognized their true meaning, and followed them to a discovery of first importance...for clinical psychiatry.'

In 1960 Dr. Laborit wrote a treatise on human physiology using Cybernetics to describe the feedback principles governing physiologic and biologic organizations. He was thus able to demonstrate the direction of metabolic pathways and to search for pharmacologic means of influencing them.

Dr. Laborit has lectured in many countries and been named titular or honorary member of six French scientific societies and of 20 foreign societies. In 1953 he was named Chevalier of the Legion of Honor and in 1957 received the Lasker award of the American Public Health Association. He has published some 350 scientific papers and many books, some of which are listed here.

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Contrary to our custom of presenting the Memorial Lecture at the meeting for 'Members of the Institute' in New York in the spring of each year, this 1963 lecture by Dr. Laborit was given on 15 August in conjunction with the International Conference on General Semantics held at New York University, University Heights Campus. The Conference had as theme 'International Communication -- its problems and opportunities', and was intended to emphasize the role of general semantics in inter-disciplinary and international communication, in clarifying differences and similarities in structural assumptions and in formulating new higher-order generalizations for improving evaluation and communication. The conference was sponsored by the Institute of General Semantics, the New York and International Societies for General Semantics (originally organized by persons who had participated in Korzybski's seminars) and by many corporations who contributed to the costs. Among the latter was the Pan American World Airways and we wish here to record our thanks to them for providing Dr. Laborit's transportation.

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For help with the translation of Dr. Laborit's text we are indebted to a number of persons, principally Stuart A. Mayper, professor of chemistry, Bridgeport University, and Severen Schaeffer, associate of the Institute. I bear the final responsibility as I did not at many points follow their suggestions, or the translation originally supplied. For instance the word finality may seem obscure. It could in some ways be considered equivalent to purpose but I prefer it for many reasons. The puzzled reader will find similar usage in Dr. Warren McCulloch's book Finality and Form.

M. Kendig, Consulting Editor