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CYBERNETICS EXPECTED AND CYBERNETICS UNEXPECTED

By

A. I. Berq, E. Kol'man, V. D. Pekelis

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13. ABSTRACT

This is a collection of articles by Soviet and non-Soviet scientists presented as a free discussion illuminating controversial and unsolved problems in cybernetics from different viewpoints. The authors of these papers oppose those who are against cybernetics as well as those who propose to substitute cybernetics for all other concrete and abstract sciences. Many of the articles deal with needed redefinitions in the area of cybernetics, with particular application to such terms as ''life,'' ''psyche,'' ''thinking machines,'' ''control of life,'' etc. Although many different viewpoints are presented, the book contains no fantasy which contradicts science but permits exercising the imagination without which scientific research is impossible.

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BEFORE WE BEGIN OUR DISCUSSION
(IN LIEU OF A FOREWORD)

Contemporary cybernetic devices model technological processes and control them, plan production, carry out calculations for materials, labor forces, wages, manage different types of transportation, solve the most complex mathematical problems, translate from one language to another, decipher ancient and encoded texts, solve strategic problems, play chess, etc. Cybernetics has found an application in biology and medicine for the investigation of physiological and specifically genetic processes, for the diagnosis of illnesses, for the replacement (during operations or illnesses) of internal self-regulating control organs, and also for prosthetics design. From cybernetics has blossomed the new scientific discipline of bionics which studies the possibility of employing the laws, methods of control, transmission, transfer and storage of information encountered in living organisms for technical purposes. Finally cybernetics has begun to equip the sciences which study psychics (pedagogy, psychology, psychiatry, gnosiology) with methods of investigation which must assist them, just as with the biological sciences, to achieve the strictness of physicomathematical sciences.

As we shall see cybernetics has penetrated not only technology and natural science, but also the social sciences and even into such fields as political economy, law, linguistics, logic, etc.

Why has the wide penetration of cybernetics into various fields of knowledge become possible and what permits it to be so "aggressive" with respect to other sciences?

It is sufficient to remind ourselves how the similarity of dynamic processes in mechanical, electrical, acoustic and other physical systems led to the establishment of general laws of dynamic modeling and to the development of a scientific discipline--the theory of oscillations. Many positions of biomechanics, biophysics and biochemistry rest on the general laws of mechanics, physics and chemistry to which everything living and non-living is subject. Therefore it is not surprising that a quantitative--in the broad meaning of this concept--similarity in the processes of communication and control, which occur in living organisms and in automatic systems, led to searches for general laws which are valid for both categories. Thus cybernetics appeared--a theoretical basis for the study of control systems in living beings, machines and society. In view of the almost boundless diversity of vitally important processes in which control occurs, it has been possible to cybernetics to penetrate practically all fields of knowledge.

It is necessary to emphasize that cybernetics does not identify the processes which occur in the living organism or in society with the processes which occur in automatic systems. Cybernetics is not interested in the qualitative characteristics of biophysical and biochemical processes which characterize living nature. It is limited to studying the question of how the living organism and the machine accomplish information processing associated with the control process. The same applies to a comparison with society.

Numerous spirited scientific discussions have arisen and do arise in the discussion of cybernetic problems.

During the course of the 20 years which cybernetics has passed in the course of its development--an extremely short period in the history of a science--it has achieved many remarkable results. First of all fundamental improvements, including semi-conductors, ferrites, printed circuits, microminiaturized components and many others has been introduced into the technical foundation of cybernetics, i.e., into "higher" automatons, computers and mathematic electron devices. As a result of this it became possible to significantly increase the speed of operation of machines to many millions of elementary actions per second and in addition to raise significantly their reliability, and to reduce their dimensions and cost. All of this, coupled with the stormy development of theory almost automatically removed from the agenda many controversial questions which naturally were generated by the new science.

For example in 1955 the French physiologist Kossa in the book "Cybernetics" decisively wrote that the machine was not capable of passing beyond predetermined frameworks, was not capable of learning or of passing from the concrete to the abstract or of accomplishing a critical function. But today most of these assertions are groundless. Man has "taught" the machine much, has expanded broadly the limits of its application and with his help the machine penetrates the sphere of activity which previously was accessible only through thought.

Human thought...a control system developed and reduced by nature to the highest degree of perfection! It is a system which possesses the broadest possibilities and an amazing flexibility in the accomplishment of the most diverse processes of information analysis, beginning with elementary calculations and ending with the analysis and synthesis of abstract concepts and theoretical generalizations. It is a system with a function which cannot be forced only into the framework of mathematical formulas and equations, which controls the entire intellectual activity of man.

The computer, created today by man, by his brain and his hands, is a collection of mechanisms and electronic elements which act strictly in accordance with the laws of mathematics and logic.

But this system is becoming increasing universal. It is capable of automatically accomplishing many information processes. Today we are witnessing how the automaton with its precisely calculated actions gradually masters one field after another, which only recently were under the direct and exclusive control and supervision of thought.

It is natural that in this connection the question will arise concerning the interrelation of machines and thought capabilities. This problem is closely connected with the basic philosophical question--the problem of the relationship of consciousness and matter. Therefore the solution of the problem requires special urgency.

Several mathematicians have proved that in principle it is possible to construct a system as complex as the human brain. In other words the capability is asserted of reproducing a reflection of the activity characteristic of human thought. Several scholars have begun to speak about feeling and thinking machines and even to discuss the prospects of the displacement of people by machines. Discussions have occurred on this basis in which Soviet and foreign scholars have participated. The most interesting statements are included in this collection.

Truth is born of controversy. As applied to the discussion at hand this means first of all that several requirements have been advanced to clarify a number of concepts which are of utmost importance for philosophy, for cybernetics and other sciences; these include the concepts "life", "consciousness", "thought", "creativity", "machine", "automaton", "information", etc. Proposals have been advanced to correct, broaden or to replace available definitions. The statements concerning the qualitative limits of the capabilities of automatons and concerning the dialectic of the final extremely large automaton, concerning self-reproducing automatons and the relationship of the living being in the technical device are very interesting.

The most important elements of the discussion concerning the creative capabilities of machines appear with particular clarity during attempts to penetrate terra incognita. Notwithstanding all the efforts of cyberneticists to dot the "i", for many the question concerning thinking machines remains a question. The fact of the matter here, of course, is not that the cyberneticists are not able to furnish a popular explanation of a specialized, very complex matter to non-specialists. The entire difficulty here lies in the philosophical lack of development of the problem. Attempts to solve this problem unilaterally will hardly be successful through cybernetics alone. This is not only a technical and not only a mathematical problem but is a profound philosophical problem and it may be solved only by a close alliance of all sciences with the philosophy of dialectical materialism.

For the present neither a single cyberneticist nor a single mathematician can decisively and clearly formulate proof of the possibility of creating a valid artificial thinking being and by the same token no one can say how such a possibility can be transformed into reality. It must be stated categorically that such problems are still impossible.

It is not out of place to mention here the words of Marx that "...Mankind always poses for itself only those problems which it may solve, since the closest examination always shows that the problem itself arises only when the material conditions for its solution already exist or are at least in the process of formation."

We can say today with complete conviction that all of the actions which replace not only the physical but also the intellectual labor of man are performed by cybernetic devices only because man has created them in accordance with a specific design and with a specific purpose which he has included in a specific program for their functioning. This is also true in a case when the machines themselves compile a program for the solution of a problem presented to them, which occurs in the more modern devices; or when they do not operate in accordance with a rigid program but consider random changes in external conditions; or, having solved a certain quantity of related problems they themselves find a method for their solution which is shorter than the initial method; or when they correct maladjustments and also when they refuse to solve a problem which is mistakenly formulated, and even in this almost fantastic case when the machines reproduce themselves or make even more modernized versions.

If the science of the future also creates artificial living material and grows artificial organisms which possess psychic elements there would hardly be any basis for considering these to be "machines" and to expand the "machine" and "living organism" concepts to the extent that they merge. This would lead to nothing by confusion.

He who does acknowledge the essential difference between the living and the non-living (and equally between the animate and the inanimate) commits no less an error than those who separate completely the living from the non-living (and the animate from the inanimate), who deny the natural origin of the living and the animate from the non-living and the inanimate.

Objectively, notwithstanding the intentions of its adherents, the view ascribes to the machine life and consciousness and which therefore considers that man and his brain are machines, has something in common with the denial of the existence of consciousness, psychics, and with attempts to reduce psychics to biochemistry and physiology to the material reaction of an organism to stimulation.

Although captivated, one should not forget that consciousness in our earth-bound human concept is, according to Lenin's expression, a function "of that special complex bit of matter which is called the human brain"[1], and that as the highest form of the reflection of objective reality the brain is a product not only of natural evolution but also of the working social activity of mankind.

A man cannot live "to think" outside society just as he cannot exist outside matter, energy fields and their effects.

Our consciousness perceives through sense organs part of the objectively and materially existing information. This process we call the representation or the reflection of the objectively existing world, of matter--of substance and energy which bears information. We live as long as and to the extent that we perceive information which produces and supports our life activity. Death is an informational vacuum for a living being. But information has a two-fold nature or rather two-fold sources which are identically important; these are nature and interaction with members of society. This interaction in the process of work also generates thought and consciousness.

Society produces the requirement for the exchange of information between its members and generates languages, codes, and all of the symbol systems for contacts between living thinking people, and for the satisfaction of their spiritual and material needs.

Intelligence is not an absolute but is a relative concept; it may be applied only to social objects. There is no meaning in speaking of "intelligence" outside society.

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[1]V. I. Lenin, Complete works, Vol. 18, p. 239.

"Intelligence" outside the collective, outside the social work activity is just as senseless as life of one "living" being in a limitless universe.

It should be stated directly that cybernetics presents a very fruitful field for conflicting views. It is here that the Leninist concept of reflection as a universal but none the less strictly differentiated property of matter may be comprehensively revealed. It is here that we must anticipate the successful analysis of complex and serious problems for science which are associated with the problem of "man and machine".

It is understandable that with the publication of similar books the disputes will not end and all the problems posed will not be solved.

Further progress in cybernetics and in other sciences will clarify a great deal with regard to complex problems and will, of course, pose new ones. New conflicts will arise and new, unexpected points of view will appear. But this is the path of science for it will never rest with what can be achieved.

A. Berg, E. Kol'man and V. Pekelis

CHAPTER 1. THE ARGUMENT SURROUNDING THE PROBLEM.

Only an Automaton? No, a Thinking Being!
Automatons and Life

A. Kolmogorov

My report "Automatons and Life", prepared for a seminar of scientific workers and aspirants of the mechanical-mathematical faculty of the Moscow State University, evoked interest among the broadest groups of listeners. A popular account of the report was prepared by my colleague at the laboratory of probability and statistical methods of the MGU [Moscow State University] M. G. Rychkova. This account is correct in all essential features, although sometimes the philological formulation of thoughts and therefore certain of their inflections belong to M. G. Rychkova.

I shall emphasize the basic ideas of the report which hold the most interest.

I. The definition of life as "a special form of the existence of albuminous bodies" (Engels) was progressive and correct, since we were dealing only with specific forms of life which developed on the earth. In the century of space travel there is a real possibility that we shall encounter "forms of living matter" (see the article "Life" in the Great Soviet Encyclopedia), which possess the fundamental properties, of practical importance to us, of living and of thinking beings, but of different structure. Therefore a more comprehensive definition of the concept of life acquires a significance which is completely real.

II. Contemporary electronic technology opens up the extremely broad capability of *modeling life and thought*. The discrete (arithmetic) nature of contemporary computers and automatons does not in this respect impose significant limitations. Systems of *a great number* of elements, each of which act "arithmetically" may acquire *qualitatively new properties.*

III. If the property of a material system "of being alive" or of possessing the capability of "thinking" is to be determined in a purely functional manner (for example, any material system with which it is possible to discuss intelligently problems of contemporary science or literature will be acknowledged as thinking), then we must acknowledge in principle the complete feasibility of the *artificial creation* of living and thinking beings.

IV. In this connection however it must be pointed out that the real successes of cybernetics and automation on this path are significantly more modest than they are sometimes portrayed in popular books and articles. For example, descriptions of "self-teaching" automatons or automatons capable of "composing" music or of writing poetry sometimes go beyond the limits of a simplified concept of the real nature of the higher nervous activity of man and in particular, of creative activity.

V. Real advancement in the direction of understanding the mechanism of higher nervous activity, including the higher manifestations of human creativity does not in any way diminish the value and beauty of the creative achievements of man. I think this is the same as placing the slogan "Materialism--It Is Wonderful!" under the heading of my report.

* * *

I belong among those extremely desperate cyberneticists who see no fundamental limitations in the cybernetic approach to the problem of life and believe that it is possible to analyze life in all of its fullness, including human consciousness with all of its complexity, by the methods of cybernetics.

The following questions are very often asked.

Can the machines reproduce themselves and can progressive evolution occur in the process of reproduction, leading to the development of machines significantly improved over the initial ones?

Can the machines experience emotions, including gladness, sadness, or can they be dissatisfied with something or want somebody?

Finally can the machines themselves formulate problems which have not been given to them by their constructors?

Sometimes the attempt is made to avoid these questions or to substantiate negative answers to them, while assuming for example a definition of the "machine" concept as nothing more than an artificial creation of man. With such a definition part of the questions, the first, for example, no longer apply. But a stubborn reluctance to investigate interesting and complex questions by concealing these with a forced limitation in terminology is hardly intelligent.

The question of whether it is possible in the course of the cybernetic approach to an analysis of living phenomena to create authentic, genuine life which will continue to exist and develop remains a vital contemporary problem. It is already an urgent problem and suitable for serious discussion for a study of analogies between artificial automatons and a genuine life system already serves as a principle for the investigation of life phenomena themselves, on the one hand, and as a method which permits searching for the means for developing new automatons on the other hand.

There is still another way to give immediate answers to these questions. This includes a reference to the mathematical theory of algorithms. It is well known to mathematicians that within the limits of each formal system, sufficiently endowed mathematically, it is possible to formulate questions which appear to be meaningful, intelligent and which must assume the existence of a specific answer, although within the limits of a given system it is not possible to find the answer. Thus for some reason it is proclaimed that the development of the formal system itself is a machine problem while thinking up the correct answer to the question is man's affair, a preemptive property of human thought.

Such an argument, however, uses an idealized interpretation of the concept of "thought", by means of which it is easy to prove that not only the machine but man himself is unable to think. Here it is assumed that man is able to give correct answers to any questions, including those stated informally, and that the human brain is capable of accomplishing complex formal calculations without restriction. However there is no basis whatsoever for representing man in such an idealized way--as an organism called infinite complexity in which an eternal quantity of truth reside. In order to achieve such a position, we note in jest, we would have to settle humanity on the stellar worlds in order to organize, by utilizing the infinity of a world, formal logical calculations in infinite space and even to pass these along as a legacy. Then it would be possible to believe that any mathematical algorithm of mankind could be developed ad infinitum.

This argument hardly has any relation to the real question. In any case this is not an objection to posing the question of the possibility of developing artificial living beings, capable of reproduction and progessive evolution, in higher forms and possessing emotions, will and thought.

This same question is presented gracefully but formally by the mathematician Turing in his book, "Can a Machine Think?" Is is possible to construct a machine which cannot be distinguished from a man? Such a statement of the question is not worse than ours and is also simpler and shorter. In fact it does not completely reflect the essence of the matter. Essentially the point of interest here is not the question of whether it is possible to create automatons which reproduce the properties of man known to us; we need to know whether it is possible to create new life, just as highly organized, although perhaps quite original and not resembling our own at all. Stories which touch upon these topics are now appearing in contemporary science fiction. The story, "Friend" in the collection of Stanislav Lem, "The invasion from Al'debaran", is interesting and sharply witty; it concerns a machine which desires to control humanity. However the fantasy of the novelist is not characterized by particular inventiveness. I. A. Yefremov, for example, advances the concept that "All perfect things resemble each other." Thus all highly organized beings must, in his opinion, have two eyes and a nose, although perhaps in a somewhat changed form. In the century of astronautics the proposition that we may collide with other living beings is not an idle one; these beings may be highly organized and may not resemble us at all. Will we be able to establish the internal world of these beings and whether they are capable of thought, whether esthetic experiences are inherent or whether they have ideals of beauty or alien ideals, etc? Why, for example, should a highly-organized being not have the shape of a thin film--or of a mold, spread on rocks?

What is Life? Is an Artificial Intelligent Being Possible?

The question which we have posed is closely associated with others: what is life, what is thought, what is emotional life and esthetic experience? In what, for example, do the latter differ from simple elementary satisfactions--from pie, for example, or something of that sort? If we speak in a more serious tone then we may state the following: the exact definition of such concepts as "will", "thought", "emotion", has not yet been successfully formulated. But such a definition is possible on the natural scientific level of strictness. If we do acknowledge this possibility we remain unarmed against the arguments of solipsism.

It is preferable to learn on the basis of facts of behavior, for example to make conclusions concerning the internal state of a living, highly-organized being.

How does one study higher nervous activity, utilizing the cybernetic approach? Here the following paths are open: first it is possible to study in detail the behavior of animals or man; secondly, it is possible to study the structure of their brains; and finally it sometimes is possible to be satisfied with so-called sympathetic understanding. If, let us say, we simply observe attentively a cat or a dog, not knowing the science of behavior and of conditioned reflexes, we may still clearly understand what they are thinking and what they want. It is somewhat more difficult to achieve such an understanding with birds, or, for example, with fish, but this too is hardly impossible. This question is not a new one; part of it has already been solved, part of it we may solve easily and part of it is difficult. Experience in the inductive development of science tells us that all problems which have remained unsolved for a long time are gradually solved and it is hardly necessary to believe that previously established limits exist here beyond which we may not penetrate.

If we consider that the analysis of any highly-organized system naturally falls within the purview of cybernetics, we must dissociate ourselves from the widespread opinion that the fundamentals of cybernetics include only the study of systems which have been previously designated aims. Cybernetics is frequently defined as a science which is concerned with the study of control systems. It is believed that all such systems possess common properties and that property No. 1 for these systems is the presence of a purpose. This is true only as long as everything that we isolate as organized systems, which control characteristic activity, resembles us ourselves. However if we wish to use cybernetic methods to study the origin of such systems, and their natural evolution, then such a definition becomes narrow. Cybernetics would hardly turn to another science to explain how an ordinary causal relationship in complex systems leads by means of natural development to the possibility of examining the entire system as one which acts rationally.

The usual concept "to act rationally" includes the ability to protect ones self from harmful external influences or, let us say, the capability of assisting in ones own reproduction. The question is asked: do crystals act rationally or not? If the "nucleus" of a crystal is placed in a non-crystalline medium, will it develop? It is impossible to distinguish individual organs on a crystal, and it follows that this is an intermediate form. The existence of such forms is inevitable.

Apparently specific problems similar to this one will be solved by the sciences which are directly associated with them. The experience of the individual sciences cannot in any way be disregarded. But we cannot exclude from the content of cybernetics common concepts concerning causal relationships in systems which act rationally and which set aims for themselves just as it is impossible, for example, in the imitation of life by automatons, not to consider the fact that these aims change in the process of evolution and the concepts concerning them change as well.

When we say that the organization of the mechanism of inheritance, which permits living organisms to pass their rational structure to descendents, has the purpose of recreating a given form, and passing to it specific properties, as well as the capability for variability and progressive evolution, who establishes this purpose? Or if we examine the system as a whole then who, except for the system itself, places before it the purpose of developing by means of eliminating unsuitable copies and reproducing the improved ones?

In summing up we may state that the study in general form of the origin of systems in which the concept of rationality is applicable is one of the main tasks of cybernetics. Here the study in general form naturally assumes knowledge abstracted from the details of physical accomplishment, from power engineering, chemistry, the capabilities of technology, etc. Here we are interested only in how the capability for the storage and accumulation of information has developed.

Such a broad statement of the problem contains within itself many difficulties but to reject this during the contemporary stage of scientific development is no longer possible.

If we acknowledge the importance of the task of defining in objective generalized terms the existing properties of the internal life (of the higher nervous activity) of a certain kind of highly-organized system which is unfamiliar to us and which does not resemble us then should we not offer the same path for application to our system--to that of human society? A common language is required, the same for all highly-organized systems, which is capable of describing all the phenomena of life in human society. Let us suppose the existence of an imaginary bystander and observer of our life who has no sympathy whatever for us nor the ability to understand what we think and endure. He simply observes a great accumulation of organized beings and wishes to understand how it is constructed. This is just the same as, for example, when we observe an ant hill. Perhaps after a certain amount of time he will be able to understand without particular difficulty the role played by the information contained, for example, in railroad time tables (an individual loses his time table and is unable to board the train required). It is true that the observer will encounter great difficulties. How, for example, is he to understand the following picture: a multitude of people arrive in the evening at a large area, and a few of them climb up on a raised platform and begin to make disordered motions while the remainder sit quietly? Finally the people all disperse without any discussion. One young mathematician, perhaps in jest, cites a different example of unexplainable behavior: the people are located in a certain area where they receive bottles with a certain liquid, after which they begin to gesticulate senselessly. For an observer on the sidelines it would be difficult to establish what this means--simply disorder in a machine, a certain kind of pause in its continuous work; or it is possible to describe what occurs in both of these cases and to establish the difference between them.

Putting aside this jesting tone we shall seriously formulate the problem which arises here; it is necessary to learn in behavioral terms to realize an objective description of the mechanism itself which is responsible for this behavior and to be able to distinguish individual types of activity of a highly-organized system. For the first time in our country I. P. Pavlov established the possibility of objective study of the behavior of animals and man, as well as the cerebral processes which regulate this behavior, without any type of subjective hypotheses, expressed in psychological terms. This intense study of the problem presented represents nothing but a Pavlovian program of analysis of higher nervous activity and of its subsequent development.

The creation of highly-organized living beings exceeds the capability of our present-day technology. But any limiting tendencies, and any skepticism or even assertions of the impossibility on rational grounds of achieving an objective description of human consciousness in all of its fullness now appear as brakes on the development of science. The settlement of this problem is necessary for even now the interpretation of various types of activity may serve as an impetus for the development of machine technology and automatons. On the other hand the possibilities for the objective analysis of the nervous sytem are now so great that it is not desired to dwell in advance on problems of any difficulty.

If technical difficulties are overcome then the question of the practical feasibility of accomplishing the corresponding work program will at any rate remain controversial.

However within the framework of materialistic ideology there are no well-grounded fundamental arguments against a positive answer to our question. Moreover this positive answer is now the contemporary form of convictions concerning the natural origin of life and the material basis of consciousness.

Is Thought Discrete or Continuous?

The theory of operation of discrete devices, i.e., such devices which consist of a large number of individual elements and operate with separate cycles, has been highly developed both in cybernetics and in the theory of automatons. Each element may be in a small number of states, and a change in the state of an individual element depends on the previous state of a comparatively small number of elements. Electronic machines are constructed in this manner and so, presumably, is the human brain. It is believed that the brain has such individual elements or nerve cells in the amount of 10^{10}, and perhaps more. The apparatus of inheritance is constructed somewhat simpler but is more grandiose within the context of capacity.

Sometimes the conclusion is drawn that cybernetics must concern itself with discrete structures only. There are two objections to this approach. First, existing complex systems, including many machines as well as all living beings, in fact possess specific devices based on the principle of continuous action. As far as machines are concerned such an example is furnished, let us say, by the role of the automobile, etc. If we turn to human activity, i.e., conscious activity, but not subordinate to the laws of formal logic, i.e., to intuitive or semi-intuitive activity, for example to motor reactions, then we will discover that the high degree of perfection and refinement of the continuous action mechanism is based on motions of a continuous-geometric nature. If a man accomplishes triple jump or a jump with six, or, for example, prepares for a distance slalom, his motion must be designated in advance as continuous (for mathematicians, the path of a slalom racer proves to be an analytical curve). It is possible to assume however that this is not a radical objection to discrete mechanisms. It is most likely that continuous line intuition in the brain is accomplished on the basis of a discrete mechanism.

The second objection to the discrete approach involves the following: clearly the human brain and even, unfortunately, often computers certainly do not always act deterministically, i.e., in a completely regular manner. The result of these actions at a certain moment (in a given cell) often depends on the case. In desiring to counter these objections, it is possible to say that even in automatons it is possible to "introduce randomness". But a simulation of randomness (i.e., the replacement of an event by some kind of regularities having no relationship with the matter) may lead to some kind of serious damage in the modeling of life. It is true that the interference of randomness is often studied somewhat primitively: a sufficiently long tape of random numbers is prepared which is then utilized for the simulation of events in various problems. But with continued use this prepared "randomness" finally ceases to be random. Based on these considerations the question of simulating events in automatons must be approached with great care. Fundamentally however this is a thing which in any case is possible.

The argument just stated leads us to the next basic conclusion.

It is certain that the processing of information in control processes in living organisms are constructed on a complex interweaving of discrete (digital) and continuous mechanisms with a deterministic action principle on the one hand and a probability action principle on the other.

However discrete mechanisms are the leading ones in information processing activities and control in living organisms. There are no justified arguments in favor of a fundamental limitation on the possibilities of discrete mechanisms in comparison with continuous mechanisms.

What is "Very Much"?

It is frequently said in connection with doubt of the possibility of modeling human consciousness on automatons that the quantity of functions of the higher nervous activity of man is incomprehensibly great and that no machine can become a model of human conscious activity in its full scope. The number of nerve cells alone in the cortex of the human brain is 10^{10}. What must the quantity of elements in a machine be in order to simulate the entire complexity of the higher nervous activity of man?

This activity, however, is not associated with disconnected nerve cells, but with rather large aggregates of them. It is impossible to imagine, for example, what kind of mathematical theorem "sits" in a single, unique nerve cell or even in a certain specific number of nerve cells, especially prepared for this purpose. Apparently the situation is completely different. Our consciousness operates with small quantities of information. The quantity of units of information which a man perceives and processes per second is quite small. Here is one somewhat paradoxical example: the slalom racer, in overcoming distance, in the course of 10 seconds perceives and processes a significantly greater quantity of information than during other seemingly more intellectual types of activity; in any case he processes more than a mathematician passes through his head during 40 seconds of tense work on an idea. In general the entire conscious life of man is somehow arranged in a very unique and complex manner but when the regularities are studied we find that the modeling requires much fewer elementary cells than for the modeling of the entire brain, no matter how amazing it is.

What volumes of information may create the qualitative peculiarity of complex phenomena which resemble life, consciousness, etc.?

It is possible to divide all numbers into low, medium, high and superhigh numbers. This specification is not strict for within the framework it is impossible to say that a specific number is a medium number or that the next one to it is a high one. The numbers are divided into categories with an accuracy of an order of magnitude. But here we do not require accuracy. What kind of categories are these? We shall begin with definitions understandable only to mathematicians.

I. We shall call the number A a low number if in practice it is possible to consider all circuits of A elements with two inputs and outputs or to record for these all functions of the algebra of logic with A arguments.

II. We shall call the number B a medium number if we prove to be not in a position to consider all circuits of B elements, but may consider only the elements themselves or (which is somewhat more complex) develop a system of designations for any system of B elements.

III. Finally we shall call the number C a large number if we are not in a position to consider in practice such a number of elements but may only establish a system of designations for these elements.

IV. Numbers will be superhigh if in practice they are impossible to make; as we shall see below, they are not necessary to us.

We shall now clarify these definitions for intelligible examples.

Let us connect to one electrical lamp three switches, each of which may be located in the left (L) or right (R) position. Then it is apparent that the possible combinations of positions of the three switches will be $2^3 = 8$. We shall count these for a clear representation:

1) LLL	3) LRR	5) RLL	7) RLR
2) LRL	4) LLR	6) RRL	8) RRR

The wiring to our switches may be done in such a manner that in each of the positions noted the lamp may either burn or not burn. If we carry out a calculation then the results show that the variant positions of the switches, accompanied by these markings, will be 2^{2^3}, i.e., $2^8 = 256$. The validity of this assertion may be checked independently by the reader by supplementing the written positions of the switches with the markings "burns", "does not burn".

The fact that such an exercise is under the control of the reader and does not take too much of his time also convinces us that the number 3 (number of switches) is a low number. If there were not three switches but five, for example, then we would have to write $2^{2^5} = 4,294,967,296$ various combinations of switch positions accompanied by the notations "burns", and "does not burn". It is hardly possible to go through all this in practice in a reasonable length of time without losing ones way. Therefore the number 5 can no longer be considered a low number.

In order to make the term "medium" number clear, we shall introduce another example. Let us examine that you are led into an area where 1,000 men are located and you are invited to shake hands with each one. It is true that your hand after this amount of exercise would not feel well but as a practical matter (with respect to time) the performance of this exercise is completely possible. You are completely capable, without confusion, of approaching each one of the thousand and extending your hand to him. But if it were proposed that an entire 1,000 of new arrivals shake hands with each other and that each company of three individuals within its own circle additionally shake hands, etc.,then this would be inconceivable. The number 1,000 then is a medium number. It is possible to say that we have "sorted" 1,000 elements by noting each one (by shaking hands).

A quite simple example of a large number is the number of visible stars on the horizon. Each person knows that it is impossible to count the stars with his finger but nevertheless a catalog of the stellar sky does exist (i.e., a system of designation has been developed), through the use of which we may at any moment obtain information concerning any star which interests us.

Naturally a computer may first of all work without confusion for a long time and secondly it sets up various circuits many times more rapidly than a man can. Therefore in each category the corresponding numbers for a machine will be greater than for man.

Numbers	Man	Machine
Low	3	10
Medium	1000	10^{10}
High	10^{100}	$10^{10^{10}}$

What is surprising in this table? It is apparent from the table that although the corresponding numbers for a machine are quite higher than for a man, a close order remained among them. Between the numbers of various categories there exists an impassable boundary: the numbers which are medium for man do not become small for the machine, just as the numbers which are high for a man do not become medium for the machine. The quantity 10^3 is incomparably greater than 10, while 10^{100} is hopelessly greater than 10^{10}. We note that the scope of the memory of a living being and even of a machine is characterized by medium numbers while many problems which are solved by so-called simple sorting are characterized by large numbers.

Here we pass immediately beyond the limits of the possibilities of comparison by means of simple sorting. Problems which cannot be solved without large-scale sorting will remain beyond the limits of machine capabilities of the highest degree of development of technology and culture.

We arrive at this conclusion without turning to the concept of infinity. We did not need it and it is hardly necessary in solving real problems which arise on the path of the cybernetic analysis of life.

Another question then becomes important: do problems exist which may be posed and solved without the necessity for large-scale sorting? Such problems must first of all interest cyberneticists, for they are capable of being solved in reality.

The fundamental possibility of creating valid living beings, constructed completely with discrete (digital) mechanisms of information processing and control does not contradict the principles of the materialist dialectic. An opposite opinion may arise only because certain persons are accustomed to seeing the dialectic only where infinity appears. In an analysis of the phenomena of life the dialectic of infinity does not appear, but rather the dialectic of the large number.

Be Careful, We are Being Carried Away!

At the present time it is probably important for cybernetics that more is being written about it than about any other science. I do not belong to the large number of enthusiasts for this entire body of literature on cybernetics, which now is being published so widely, and see in it a large quantity, on the one hand, of exaggerations, and on the other hand, vulgar simplification.

One cannot, of course, say that in this literature assertions are made concerning that which is in fact unattainable, but one frequently encounters enthusiastic articles where the headings themselves shout about successes in the modeling of various complex types of human activity, which in actual fact are modeled quite poorly. For example, in American cybernetic literature and in our own one may occasionally encounter works concerning the so-called music composing machine even in quite serious scientific journals. (This does not apply to the work of R. Kh. Zarinov). By this the following is usually understood: the memory of the machine is "stuffed" with the musical notation for a large number (70, let us say) of cowboy songs or, for example, church hymns; then the machine, according to the first four notes of one of these songs, searches through all of the songs where these four notes are encountered in the same order and, having chosen one of these at random, takes from this song the next fifth note. Then the machine again has four notes (two, three, four and five), and again the machine accomplishes the search and selection in the same manner. Thus the machine, as if by touch, "creates" some kind of new melody. Here it is maintained that if the memory of the machine contains cowboy songs then in its creations one would hear the "cowboy" influence, and if the memory contained church hymns then one would hear something "divine". It may be asked what would happen if the machine would conduct a search not by four, but by seven notes in a sequence? Since in reality two compositions which contain seven identical notes in sequence would practically never be encountered, obviously the machine, having played seven notes from some song, would be forced to play the song to the end. If, on the other hand, it is sufficient for the machine to know only two notes for genuine creativity (compositions with two identical notes are legion), then here the machine would be presented with such a wide selection that instead of a melody from the machine we would hear a cacophony of sound.

This entire uncomplicated circuit is presented in literature as the "machine composition of music", in which it is seriously declared that with an increase in the number of notes required "for priming", the machine will begin to create music of a more serious, classical nature, and with a decrease in this number the machine will shift to contemporary jazz music.

Today we are still very far from the accomplishment of an analysis and a description of the higher forms of human activity; we have still not even learned in objective terms to give definitions for many categories and concepts encountered here in not only the modeling of such complex types of this activity which includes the composition of music. If we are not able to understand how living beings which want music differ from beings which do not want music then by proceeding immediately to the machine composition of music we find ourselves in a position of modeling only purely external factors.

The "machine composition of music"--thi, is only an example of the simplified approach to cybernetic problems. Another widespread shortcoming consists of the fact that adherents of cybernetics are so involved in the possibilities of the cybernetic approach to the solution of any of the most complex problems that they permit themselves to disregard the experience accumulated by other sciences during the long centuries of their existence. They frequently forget that the analysis of higher forms of human activity was begun long ago and has extended over a long period. And although this analysis has been conducted in other, non-cybernetic terms in essence it is objective and it must be studied and utilized. Those who are able to make cybernetics "with bare hands" and raise such a sensation around it frequently do not pass beyond the framework of investigating the most primitive phenomena. Once at a meeting in the Moscow House of Writers one of the participants made a speech to the effect that our time must create and had already created a new medicine. This new medicine was the achievement and an article of study not of medical men, but of specialists in the theory of automatic regulation! The most important point in medicine, in the opinion of the speaker, is the cyclic processes which occur in the human organism. These processes are exactly described by differential equations, studied in the theory of automatic regulation. Thus the study of medicine in medical institutions has become obsolete--it must be transferred to the control of engineering colleges and mathematics faculties. Perhaps it is correct that specialists in the theory of automatic regulation may have their word in the solution of individual problems which now confront medicine. But if they wish to participate in this work then first of all they are required to possess high qualifications for the experience accumulated by medicine, which as the oldest of sciences is tremendous and in order to do anything serious in it, the science must first be mastered.

Why Only Extremes?

In general the analysis of higher nervous activity in cybernetics is concentrated for the present in two extreme poles. On the one hand cyberneticists actively participate in the study of conditioned reflexes, i.e., of the simplest type of higher nervous activity. Apparently it is clear to everyone what a conditioned reflex is. If two stimulants of some type are repeatedly accomplished simultaneously (for example, a bell is rung simultaneously with the delivery of food), then after a certain amount of time only one of these stimulants (the bell) causes a responsive reaction in the organism (salivation) to the other stimulant (the delivery of food). This association is temporary and if it is not reinforced it gradually disappears. A significant portion of cybernetic problems, which are now known under the name of the mathematical theory of learning, encompass very simple schemes which do not exhaust even a small fraction of the entire complex higher nervous activity of man and in an analysis of conditioned-reflex activity itself represent only an initial step.

The other pole is the theory of formal-logical decisions. This side of the higher nervous activity of man yields well to study by mathematical methods and with the creation of computer technology and computer mathematics, investigations of this type have moved forward rapidly. Here cybernetics has been quite successful.

The whole tremendous expanse between these two poles, that is between the most primitive and the most complex psychic acts (even such simple forms of synthetic activity as, for example, the mechanism of the exact calculation of geometric motion, which we spoke about earlier, for the present yields poorly to cybernetic analysis) has been studied very little if it has been studied at all.

Cybernetics and Language

A special position is now occupied by mathematical linguistics. This science has only recently been created and is developing in proportion to the accumulation of cybernetic problems associated with language. It deals with the analysis of higher forms of human activity or more on the intuitive side than of a formal-logical nature, for this activity yields poorly to exact description. Everyone knows what a grammatically constructed phrase is, and the correct agreement of words, etc., but for the present no one can adequately pass this knowledge to a machine. An exact, logically and grammatically faultless machine translation would now be possible, perhaps, only from Latin and to the Latin language, for the grammatical rules of this language are sufficiently complete and unambiguous. The grammatical rules of new, living languages are apparently still insufficient for the accomplishment with their help of machine translation. Here the required analysis has been going on for sometime and at the present time machine translation has become the subject of broadly and seriously applied activity. It is possible, perhaps, to say

that it is specifically in this area that the basic attention of mathe-
matical linguists has been concentrated. However in theoretical works
on mathematical linguistics one circumstance has been insufficiently
studied; this is the fact that language arose significantly earlier than
formal-logical thought. It is possible that for theoretical science
one of the most interesting investigations (in which the ideas of cy-
bernetics, the new mathematical apparatus and contemporary logic may
be successfully combined) is the investigation of the process of forma-
tion of words as a secondary signal system. Initially, in connection
with a total lack of concepts, words entered into the role of signals
which generated a specific reaction. The emergence of logic ordinarily
refers to comparatively recent times; apparently only in ancient Greece
was it clearly understood and formulated that words are not simply
the designations of certain direct concepts and images but that the
concept might be isolated from something in the word. Prior to genuine,
formal logical thought, ideas arose unformalized in concept, and as a com-
bination of words which brought other words after them as an attempt to
establish directly a flow of images passing before our consciousness, etc.
Tracing this mechanism of the crystallizing out of words and signals
which carried a complex of images and developing early logic on this
basis are extremely rewarding fields of investigation, especially for
the mathematician. Incidently this subject has been repeatedly touched
upon in cybernetic literature.

The following question may also be interesting: how is logical
thought formed in a man? We shall attempt to trace the stages of this
process in an example of the work of a mathematician over a certain pro-
blem. At first, apparently, the desire arises to investigate one question
or another, followed by an approximate, emerging concept of unknown origin
which reflects what we hope to obtain as a result of our investigations
and the methods by which we hope to obtain this result; during the next
stage we start our internal "adding machine" of formal-logical reasoning.
This is apparently the path of the formation of logical thought, a plan
of the creative process. It may probably present some interest to inves-
tigate not only the first, intuitive stage of this process but also to
set a task of creating a machine capable of helping man in the creative
process during the stage of concept formulation (for a mathematician,
for example, during the stage of formation of calculations) in order to
entrust to such a machine the understanding and establishing in complete
form of certain unclear, supplementary outlines of figures and formulas
which every mathematician jots down on paper in the process of creative
searches, or, for example, the reconstruction from drafts of the repre-
sentation of figures in multi-dimensional space, etc. In other words it
is interesting to think about the creation of machines which, while not
replacing man, are already in a position to help him in complex creative
processes. For the present it is still difficult even to imagine in what
manner and by what method such a machine could be realized. But

for the present this problem is far from being solved. Conversations concerning all these questions have already been raised in cybernetic literature, which apparently we can only welcome.

As we have already seen from several examples cited here, there are many different problems associated with the understanding of the objective structure of the smallest areas of higher nervous activity in man. All of these deserve the responsible attention of cyberneticists.

Materialism--It's Wonderful!

In conclusion we shall dwell upon questions touching upon, if we may say so, the ethical side of cybernetic ideas. The often-encountered hostility and denial of these ideas emerge from a lack of desire to acknowledge that man is in fact a complex material system, but a system of finite complexity and of extremely limited development and therefore may be successfully simulated. Many find this concept to be degrading and strange. Even after accepting this idea people do not reconcile themselves to it; such a picture of the universal penetration of the secrets of man, even to the possibility, so to speak, of "encoding" him and "sending him by telegraph" to another place seems to these people to be repulsive and frightening. Misgivings of another sort are also encountered; will our internal structure even permit exhaustive objective description? It was proposed, for example, to place before cybernetics the task of learning to distinguish from objective indicators beings who want topical music from beings who do not want it. We analyze and analyze and it turns out that in actual fact there is no intelligent basis for isolating such music as noble in comparison with other harmonies.

The concept appears to me to be important that there is nothing degrading and strange in this aspiration to comprehend ourselves to the ultimate. Such impressions may arise only from half knowledge; real understanding of the entire magnificance of our capabilities, the sensation of the presence of eternal human culture, which comes to our aid must generate a tremendous impression and must evoke admiration! Our entire structure would be comprehensible but comprehensible to the extent that the structure contains within itself immense and unlimited capabilities.

In fact we must attempt to replace this silly and senseless fear of our simulation by automatons with the tremendous satisfaction inherent in the fact that such complex and wonderful things may be created by man, who not very long ago thought that simple arithmetic was something incomprehensible and lofty.

MACHINE CANNOT LIVE, AND MOLD CANNOT THINK!

ONCE MORE ON A SENSE OF SIZE

E. Kol'man, Academician of the Czechoslovakian Academy of Sciences

Is is true that man is a machine, the most modern of most cybernetic machines known to us at the present time? Is it is true that there is no difference between a cybernetic machine of sufficiently high organization and a man, i.e., between the "artificial" and the "natural" method of machine creation?

Is it true that machines may have psychic qualities, that they may experience emotions, rejoice, be sad, be unsatisfied with something or want something?

More than 200 years ago the outstanding French materialist philosopher and surgeon Julien Offray La Mettrie published his composition, "Man, the Machine." In it he proved that the laws for living and non-living matter are the same. Living matter differs from non-living matter only quantitatively, that is by significantly higher complexity. At the time these materialistic metaphysical views were quite progressive and their author was persecuted by the church.

La Mettrie observed correctly that psychological and physiological phenomena do not occur without physical and simply mechanical phenemona. Then he mistakenly concluded that the former are reduced to the latter, that man is a machine, and that between man and machine there are only quantitative differences. He did not observe that lower forms of motion are preserved in higher forms not independently but only as subordinate, secondary forms; during the transition from the lower forms to the higher; not only quantitative but also qualitative changes occur and something fundamentally new appears. Therefore an explanation of higher forms cannot be made comprehensive through a study of the lower forms.

One hundred years have passed. The natural sciences have developed intensively. Scientific philosophy--*dialectical* materialism was created by Marx and Engels. This science examines not only the material unity of the living and the non-living but also their qualitative differences. Although living beings are subject to the same material, physical and chemical laws as non-living matter, they are not subject to these alone. Living beings have their own inherent and specific biological conformities with law. During the transition from the non-living to the living state an abrupt change occurs. In this sense there is a fundamental difference between the living and the non-living states.

Of course, more than 100 years have also passed since Marx and Engels made their study. The development of natural sciences has been exceptionally intensive. Therefore the question naturally arises--should we not reexamine all of their views just as in connection with the beginning of cybernetics? Marxism itself requires that its individual positions be reexamined if this is required by new scientific discoveries.

However in the given case there is no basis for such a reexamination. The reverse is true. Cybernetics merely confirms again one of the basic positions of Marxism--the study concerning quality and quantity.

Cybernetics is a mathematical science. It studies any self-controlling systems independently of whether they are partially equivalent or whether they are organic, or even social systems; however it studies these from the quantitative viewpoint alone (in the broadest meaning of this word, i.e., not only in the sense of number or value, but also in the sense of order and structure).

It is here that the strength of cybernetics lies. The discovery of a community of quantitative control regularities made it possible, for example, to model thinking operations with the aid of computers and, on the other hand, to utilize the experience of work with computers for a study of the central nervous system of man.

But unity is not uniformity. That which creates the strength of cybernetics also includes its weakness, or at least a great temptation not to see the differences between man and machine due to their similarities.

Those who maintain that man is a machine and that cybernetic devices think, feel, have a will, etc., first of all miss one "detail"--the historical approach. Machines are a product of the social-labor activity of man, while man is a product of natural evolution. Here the material base is different--in the first case cells of organic material are involved, while in the second there are electron tubes, transistors, etc., and the time scales are incommensurate. For this reason it is incorrect to obliterate the difference between "natural" and "artificial."

It is true that other arguments may be used as well in order to defend the theses "Man is a Machine" and "The Machine Thinks."

It is said that it is not necessary to limit strictly understanding of the terms involved. For example, if we define "machine" as just something which is artificially created by man, then it is clear that a machine cannot reproduce its own kind nor by the same token can machines improve over the original ones.

What is right is right. Such deliberately narrow definitions may be given only by the narrow-minded enemies of cybernetics. These definitions are also advanced by those who, as adherents of vitalism, the study which attempts to explain the phenomena of life with the aid of some kind of special far-fetched "forces" or "principles," draw an impassible boundary between living and non-living matter. However in addition it must be said that even machines capable of self-reproduction and self-improvement had these remarkable properties exclusively because of the fact that in the final analysis they were given by the designers concept.

All, including the most complex "machines fulfill only *auxiliary* operations in agreement with *purposes*, established by man." A. N. Kolmogorov ended his article "Cybernetics" in the Great Soviet Encyclopedia (Vol. 51, 1958) with these words, and they remain valid as before. No factors which prove otherwise exist. Machines do not exist which can set up problems for themselves not posed for them by their constructors, since machines, for example, which develop for themselves a program for their work or even those which create scientific hypotheses do this only because this self-programming or hypothesis development was programmed into them.

But is this entire matter really only one of definitions? Does it not all depend on what we arbitrarily call a machine? Why not expand the definition of a machine far enough so that it also encompasses man?

But this argument does not apply. Definitions cannot be expanded arbitrarily for they must correspond to reality. In any logical dispute it is possible to prove anything convenient with the aid of arbitrarily expanded definitions. For example, there are no differences between dogs and chairs because both are "four-legged," or there are no differences between the proletariat and capitalist because they are both "producers." This is rather adroitly done by several contemporary Anglo-American sociologists so that they can "eliminate" the class struggle, once and for all. Similarly it is possible to expand the "machine" concept to the entire universe, to call it a "clock," and then legally raise a question concerning the "watchmaker," the creator. This means that an examination of the definition of a machine does not lead to proof that man is a machine and that a machine thinks.

Let us assume this, but should we not reexamine the concept "life?" The belief that life is a method of existence of albuminous bodies, as defined by Engels, is now too narrow. It is possible that as a result of the development of astronautics we shall meet other forms of life, not based on high-molecular carbon compounds. Why not then define "life" so that it also encompasses the work of cybernetic devices?

Although there is a grain of truth in this argument, we cannot consider it to be well-grounded. Apparently it is true that life cannot be defined on the basis of chemical structure but the definition must be based on life functions: assimilation and dissimilation, growth, self-reproduction and first of all self-regulation of the exchange of matter and energy with the environment. It is quite possible that in the future, and possibly not very far in the future, cybernetic devices will be constructed which model such functions. This, however, does not imply that they will become living machines.

A subsequent argument in favor of "living machines" is as follows. If they are not built today, then they will be built tomorrow. Instead of electron tubes, transistors, ferrites, printed circuits, cryotrons and other devices of contemporary electronics, the machines will employ albumin, living cells, and a living brain will be created in the laboratory.

Let us assume this. But is it really not clear that these cybernetic devices will begin to function on a living basis, and therefore will differ fundamentally from contemporary computers? But it is to the latter that some wish to attribute the ability to live and to think.

However in connection with the current state of science, cybernetic devices constructed fully or partially with the use of living elements must be relegated for the present to the realm of dreams. We would like to see some dreams realized immediately. But first of all it is necessary to perform a great deal of difficult work in order to create the condition which will permit us to enter upon the realization of these dreams. In fact even "ordinary" cybernetic devices have not yet found the distribution and penetration which they must find. Many problems within the field of cybernetic technology, solved in principle, are still technically not realizable. What shall we say about the biochemical, physiological, and psychological bases of these future cybernetic devices which we can only daydream about!

It is completely natural that the creators of fantastic novels range far into the future. Belyayev, for example, revived a dead brain, and Lem joined a living brain with a cybernetic device while the astronomer Hall described the possibility of direct influence on the human brain of advanced living beings of "the White Cloud," which had invaded our planetary system. However scholars are obligated to combine the boldness of fantasy with soberness of mind. One cannot squeeze scientific investigations into the narrow framework of practicality. But aside from this science must direct its maximum efforts toward the solution of the most vital problems of the present day.

These remarks do not at all limit the possibilities of cybernetics. Those who propose to limit cybernetics to the field of technical automatons alone are its enemies, but today they cannot merely call it a "pseudo-science," or a "complete hoax." There are many of these and we must struggle against them. Some who oppose the application of cybernetics to biology, to psychology and in particular to the social sciences declare that they allegedly protect these sciences from mechanization, and from the "reduction of the highest forms of the movement to lower forms." But if cybernetic methods are employed in biology, in psychology or in the social sciences through the control of the specific methods for a given science, no "reduction" exists. But we must not forget that the opposite enthusiasm is no less dangerous. He who replaces biological, psychological and similar methods with cybernetic methods, who identifies the living with the non-living, the animate with the inanimate, and society with nature willingly or unwillingly promotes hylozoism, and panpsychism and social Darwinism, which, just as vitalism, lead in the final analysis to idolatry and to reactionary views of the world.

In this case is it not true that through cybernetic methods it is possible to analyze life in all of its fullness, including human consciousness in its entire complexity? Yes, we are in complete agreement with this. Moreover, we shall add without the slightest hesitation that cybernetic methods may be and must be employed for the analysis of social phenomena as well. We express ourselves decisively against conservatively thinking biologists, psychologists and surgeons (and against economists and philosophers as well) who fear cybernetics as the devil fears incense. However we object just as decisively to the concept that cybernetic methods may replace the methods of biology, medicine, psychology, political economy, etc.

Is it not also true that as we travel along the path of cybernetic development toward an analysis of living phenomena, we may create real and genuine life which will continue and develop independently? We can and do agree with this but only in the sense that this approach will be of important assistance to biochemistry in order to achieve through specific biochemical methods the artificial synthesis of albumin and living material. However if anyone assumes that such artificial living beings, capable of reproduction and progressive evolution and possessing emotions, will and thought in the highest forms will be constructed from the non-living substance of the automaton, then he is greatly mistaken. No matter how high their order, they will be only a part of technology, which is an artificial medium which society places between it and nature in order to subordinate natural elements to its purposes. Automatons will always be only derivatives of man and they will execute physical actions only. Man alone, regardless of the "free run" which he gives the machines, will always stand near the cradle; he alone will rationally interpret their actions in ideas, which without this interpretation would remain only physical actions.

Nevertheless certain people are convinced that it is possible to create automatons which not only possess all the properties of a man, i.e., automatons indistinguishable from man, but also those which will possess qualities of highly-organized living beings unfamiliar to us, living in other worlds and completely dissimilar to us. It is as if this would facilitate our task of analyzing the psyche of these Gods of Olympus, if in the future we encounter them as a result of space travel.

All this sounds quite fascinating, doesn't it? But scientific truth is above all. Fantasy is good but groundless fantasy leads nowhere.

First of all it is not correct that cybernetic automatons may reproduce all the properties of man, his entire psyche, or that they may become indistinguishable from living people or even animals. These devices cannot be charged with anything more (and this is not a small order) than recalling in connection with conditioned reflexes, thought activity operations; in this connection it has already been pointed out that this certainly does not mean that they are thinking. A tremendous area of brain functions, which cannot be described formally, cannot be transmitted to machines.

Of course one may make the assumption that this limitation is only a temporary one, that in the future we will succeed in formally describing the sensations, perceptions, emotions, wills, temperament and nature of man and then there will be no fundamental obstacles to the reproduction of these qualities by cybernetic devices. Although in our time it is hardly possible to imagine even hazily the avenues of approach for the solution of the problem, we certainly do not intend to dispute the legitimacy of this assumption. We shall only require that those who express this and those who are acquainted with it are clear that this is only an assumption, a hypothesis, and is far from reality.

How shall we understand the concept of extremely highly-organized beings which at the same time are completely unlike us? If they do not resemble us at all then this is because their physical chemical basis is different, for example, not carbon but silicon, not oxygen but fluoride, or they not be solid bodies but perhaps may be liquid; finally it is possible that they are made of some forms of matter unknown to us--particles and fields, or from some other substances unknown to us. If in this connection they present a certain similarity to living beings it is in the sense that they possess the property of self-regulation of material exchange with the environment. If in addition they are highly-organized, then they have the capability of transforming this environment, of creating their own artificial environment, their own "technology", and on the basis of this "labor" process to develop their property of reflection to an extremely high degree.

It is clear however that just as it is naive to represent that all highly-organized beings must have a pair of eyes and a nose between them just as we have, it is just as naive to assume that the regularities in their functions of controls and reflection are so close to ours that we may model these with cybernetic automatons. It is a joke to say or to establish what kind of internal world these beings have! Laplace once expressed the idea that in order to communicate with Martians we should construct an intensively illuminated Pythagoras theorem on the plains of Siberia so that they would know that thinking beings inhabit the earth. At the present time some people believe that this same purpose may be served by powerful radio signals of proper sequence. However if we, for example, assume that somewhere in the Great Nebula in Andromeda there are highly-organized beings, and if they, for example, are watery inhabitants of a watery environment, they would have no metric geometry, nor even arithmetic in our sense, and therefore it would be impossible to establish any kind of contact between them and us by means of concepts in these sciences. If with the aid of cybernetics we are successful in deciphering the ancient writing of the Mayan Indians then it is only because we have common concepts with them which reflect a community of environment. If somewhere there exists a world which is constructed of antimatter then we shall not be able to agree with the inhabitants even about where left and right sides are.

In general, ascribing to hypothetical beings, completely foreign to us, a certain psyche similar to our own (thought, emotions, esthetic experiences) has just as little basis in fact as believing that while being attracted to each other, unlike electrical charges experience a feeling of love and that while beings repel from each other like charges experience hate. Anyone who reduces his arguments concerning beings which are completely unlike us but which possess a psyche similar to our own must, if he carries his arguments to their logical conclusion, pass to hylozoism and panpsychism, to the study of the all-pervasive animation of matter, to the negation of qualitative changes during the transition from non-living nature to living nature and even to highly-organized nature, capable of thinking.

Some scholars answer the question "Is an artificial thinking being possible?" in relation to the development of exact definitions of such concepts as "thinking," "emotion," "will," etc. In this connection they feel that specific definitions do not exist, although (on the level of strictness of natural science) they may be developed. It seems to us that they unjustly reproach physiology, psychology and philosophy, which have given us these definitions long ago. Is this not the case, for example, with the definition of thought as "an indirect, abstract and generalized reflection of objective reality," or as "a higher product of the brain, a higher product of matter?" It is another matter that such definitions may be considered as insufficiently developed and exact, or too narrow. Naturally with the development of a science its definition must also develop, but the entire question is on what basis and in what direction; will this definition be founded on the basis of new, scientifically established data and in the direction of a more intensive agreement with reality or will it be based on subjective desires and sympathies in the direction of fantasy?

There are no experimental bases for extending the definition of *thinking*, as well as for *sensation*, *will*, etc., to all matter. There are no scientific arguments for the reexamination of Lenin's position that "In its clearly expressed form sensation is associated only with the higher forms of matter (organized matter)" and that "It is possible only to assume the existence of a capability conformable with sensation in the structural foundation of matter."

It is correct to note that one of the reasons encountered up to the present time for the negative attitude toward cybernetics is purely a psychological one. Notwithstanding the fact that cybernetics has existed as a science only since 1948, its achievements are amazing. To one who knows about cybernetics only from popular publications, the picture is often presented of life among automatons, which have taken over the lions share of the physical and mental work of man. For some this is extremely tempting, while for others it evokes fear. In other words, some people do not wish to become reconciled to the fact that the automaton may imitate their thinking activity, which seems to them to be a privilege of the "tsar of nature" alone. Others allow themselves to be carried away to the opposite extreme by the same psychological grounds which have brought success to cybernetics, which are capable in fact of making the head spin. In this respect they were not able to avoid the danger which Norbert Wiener, the founder of cybernetics, repeatedly warned against (although he himself often yielded to temptation); the warning included the influence of the idea of the so-called "cybernetic philosophy," metaphysical exaggerations which attempt to establish the cybernetic method as a single and universal method and cybernetics as the science of sciences. In his lectures Professor Wiener said, "There exists a Jewish legend of the Middle Ages that a Rabbi Lev ben Betsalel, who lived during the time of the Emperor Rudolph the II, created a "golem," a clay slave, as a woodchopper and water carrier. He animated this by placing in its mouth a note with the cabalistic God name of "Shem." However, the Rabbi went out once and forgot to remove the note; the golem chopped up all his furniture and flooded his quarters. Then he threatened the entire region until the Rabbi himself destroyed the "golem." The same plot was also used by Karel Capec in his drama, "RUR." "Cybernetic devices," continued Wiener, "cannot only reproduce themselves but can also produce devices which are improved to a greater and greater degree. But the most complex devices are the ones which fail easily. Does not the case here involve man? The workers who will service these devices must be of incomparably greater development than workers on an assembly line. But the more educated a man is the less he is inclined to subordinate himself to a strange will. If the machines do not also revolt against man, then the danger that society will disintegrate is very serious..."

Wiener's novel "The Tempter" (a translation of which will probably be published in Russian) reveals that Wiener sharply defended the defects of contemporary American society. But Wiener, of course, was not a Marxist. He does not understand that the danger of a revolt of man against automation was entirely determined by the exploitational dehumanizing essence of capitalism. A man in communist society will consciously subordinate himself to collective discipline and the will of the collective becomes his will. Realizing that it was planned to employ cybernetics for nuclear rocket war, Wiener was not able to destroy the golem which he himself had created.

Norbert Wiener's small book "Man and God," published in the year of his death (1964) was devoted to these ideas which he traced clearly. Similar to Einstein, who felt deeply his responsibility before mankind in connection with the fact that with the formula $E = m \cdot c^2$ he had unwillingly opened up a path for the military use of nuclear energy, Wiener also tortured himself over the idea (he spoke to me about this himself in the fall of 1964 during the Congress on Cybernetic Medicine in Naples), that his child, cybernetics, might serve the purpose of the destruction of peoples and the annihilation of humanity. Unfortunately Wiener did not understand to the end that neither cybernetics nor science itself but the social structure was guilty of the fact that the most important achievements of human genius are turned against the people.

It follows from what has already been said that this problem cannot be investigated without philosophy. The problem of the relationship between the living and the non-living, between the animate and the inanimate cannot be solved by the individual natural sciences. It can be solved solely by philosophy on the basis of the results obtained by these sciences.

It is true that several of our philosophers in their own time have declared the most progressive scientific theories, with which they were only superficially acquainted, to be "idealistic" or "metaphysical," and have thus contributed to the situation where present-day natural scientists have turned away from philosophy. It is true that the recidivists still appear, for example, when several philosophers declare a sensitive appreciation for contemporary atomic physics to be idealism, and others proclaim the existence of a crisis in physics in capitalistic countries, etc. To confuse individual philosophers with philosophy is no less a mistake than confusing cybernetics with the over-free declarations concerning it by several Western publicists.

In November 1954 I had to speak publicly for the first time in defense of cybernetics against those Marxist philosophers who called it a "pseudo-science." Then I pointed out that one of the reasons for their inherent reaction "in view of their complete lack of knowledge of cybernetics" was incompatability with dialectical materialism, and in particular social-political reactionary conclusions which several persons in capitalistic countries have drawn from this. Then many Soviet natural scientists, surgeons, mathematicians and even engineers, which worked in the automation field, were inclined against cybernetics.

Of course at the present time one will hardly find a critic who declares that cybernetics is a "complete hoax." But the enemies of cybernetics remain--they have only changed their tactics. In words they pay homage before its successes, and several even flaunt the use of the fashionable expressions "feed-back," "information channel," etc. But they do not desire to learn, they do not desire to master new methods and to apply these in biology, medicine, psychology, and economics or to involve themselves in their well thought out philosophical generalization. They pretend that this laziness of thought is a struggle against mechanization, while it is completely clear that any mechanistic statements by individual cyberneticists are to their advantage.

To date however one may encounter among Marxist philosophers those who have come up against the opposite extreme. We hear statements from these in which *information* is neither matter nor consciousness and pronouncements which smack of the positivistic, evoked by mixed concepts of *information* and *quantity of information*, as well as ambiguities which can be solved immediately on the materialistic basis of the Leninist theory of reflection. Their desire for the universal application of cybernetics is clearly expressed; under *feed-back*, for example, they place every inverse action, every interaction in general, and they consider self-regulation to be conformity with law which applies everywhere, in all degrees of development of the universe. From this comes their exaggerated declarations to the effect that the revolutionary effect of the discovery of cybernetics may be compared with the discovery by Marx of the laws of social development; that cybernetics, more than other sciences, is essentially a dialectic science; that it represents a special intermediate link between philosophy and a number of specialized sciences; that Marx was the first cyberneticist, that his economic plans for reproduction in "Capital", and also the policy of the Marxist-Leninist Parties must be considered as an application of cybernetics...all this is confusion which renders a disservice both to cybernetics as well as to our philosophy.

Cybernetics, along with atomic physics and astronautics, belongs to the most progressive fields of contemporary science. But just because it opens up for us unaccustomed communications links (analogies between the control functions of machines, organisms and social systems), it still collides with misunderstanding and a negative attitude on the part of present-day conservatively-thinking people. On the other hand some of these, who have penetrated the meaning of its exceptional significance, close their eyes to the limits of its capabilities. Both of these groups act according to inertia, along the lines of least resistance, and yield to the "awful force of habit" of thought, against which Lenin repeatedly warned.

But cybernetics is called upon under conditions of the communist society to help man most effectively overcome this inertia of thought, the struggle against which demands greater, more resolute efforts than overcoming the inertia of material bodies. Cybernetics has not one, but four basic functions: to free man from monotonous actions of physical and mental labor, to serve biology and medicine, to help economics and sociology; to assist logic, psychology, psychiatry, pedagogy and gnosiology to become exact sciences to the maximum extent. These functions, of which the second, and in particular the third and the fourth which will display their validity only in the future, are of ever increasing significance, and will bring to new communist man a happy and joyful life in a society where the structure and moral level of its members will harmonize with the highest technology which will no longer serve for the enslavement and annihiliation of man.

In any specialized science cybernetics (just as mathematics) may be employed fruitfully if it is based on the principles of this specialized science (for example, geology or medicine), and no attempt is made to subordinate these principles to cybernetic principles. Einstein correctly noted that if we disregard real phenomena, then mathematically (cybernetics is a mathematical science) it is possible to prove whatever we wish.

In order that cybernetics may fulfill its third function, and so that it can stand at the service of scientifically controlled society it is necessary that it develop in accordance with principles developed by Marx in "the Civil War in France" and Lenin in "State and Revolution" for a Communist society and its first (socialistic) phase (considering, of course, the newest experience in the building of socialism). Only under this condition will the cybernetic model of scientifically controlled society be not only a toy of the intellect, but will reflect reality. Then, if we impart a cybernetic structure to this model we will be able to obtain the solution to problems which arise during the development of society and we will be able to plan this development to the optimum degree.

What kind of cybernetic model will this be and what conditions must be maintained for it? The model must have no idle and overloaded elements. Negative feed-back links in the system must eliminate deviations (which inevitably appear in the process of development) from a state of dynamic equilibrium. All sub-systems must act not in accordance with a rigid program, but with consideration of random fluctuations, as well as local and temporary peculiarities. Information must flow along communications channels equally well in both directions--from the "brain" to the "peripheral organs" and vice versa with minimum distortions. The "memory" must have maximum volume and maximum variety. Of course such a society will be arranged so that with minimum expenditures on production and distribution of material and cultural goods, it will guarantee all its members the maximum use of these goods.

As far as the fourth function of cybernetics is concerned today a mathematical theory is already being developed of its applicability to teaching, based on certain assumptions concerning the dynamics of habit formation. Although this theory for the present is only phenomenological, in that it does not analyze processes which occur in the cortex of the human brain during habit formation, but only describes their results, it nevertheless gives us a quantitative picture of how, under different circumstances, a habit is reinforced, or, on the other hand, is lost, and this gives us the opportunity to evaluate the complexity of the "mechanism" which controls these processes. This is one of the paths--

and today we stand only at the beginning--which will lead to the transformation of pedagogy into an exact science.

Another cybernetic method which leads in the same direction is that which gives to man the possibility of managing the gigantic, and increasingly large quantity of scientific knowledge. Cybernetic information devices which can extract the required data in the course of several seconds from millions of similar information files already exist in our time.

The third path which leads to an improvement in the teaching process is only a dream today. It will be realized only when we are successful with the help of cybernetic devices of obtaining a detailed analysis of the operation of the brain, and this in turn will permit direct intervention in the processes which occur in the brain during construction. Since this is only the "music of the future", it is a possibility which is very, very far away.

First of all, however, cybernetics must develop uniformly, it must be widely introduced, and it must overcome prejudices which oppose it. Only under these conditions may cybernetic devices help man to raise his logical, methodological culture to a new, higher level and to observe and evaluate correctly, without underestimates or exaggerations, the birth of the new and dying out of the old. This is why it is so important that excessive obstacles do not appear in the path of cybernetic development, or in the path of its introduction into our socialistic and communistic society. Among these obstacles are metaphysical exaggerations, which are capable of evoking an undersirable idea of confusion in many, especially when they are expressed by outstanding scholars who are respected specialists in their fields.

THE THERMODYNAMIC RIDDLE OF LIVING MATTER

Dr. of Biological Sciences K. Trincher

The opinion exists that any function of living matter, no matter how complex, may be modeled and that the fundamentally unlimited reducibility of biological phenomena to physicochemical processes is proved by this fact--by the possibility of the material modeling. Since physicochemical processes in a modeled mechanism may be completely studied in principle, then it follows therefore that the modeled function of a living system supposedly may also be fully studied in the physical-chemical aspect. The error of this position may be proved on the basis of the second law of thermodynamics.

Two fundamental concepts are included in the formulation of the second law; these are energy and operations. The transformation of one form of energy into another through the medium of operations occurs under conditions or irreversibility with a certain energy depreciation in the form of heat. With the occurrence of operations over an unlimited period of time in an isolated system possessing a certain store of free energy, the transformation of the entire free energy into heat must occur. This state, which designates the cessation of all operations is also the attainment of stability in an isolated system--the state of maximum entropy, or the most probable state (The Clasius principle). In the classical statement of the second law of thermodynamics only diffusion energy is the source of increasing entropy. In fact, however, one more source of increasing entropy exists--wear of the machines.

A machine is a cyclic operating mechanism which in the course of transforming energy of a specific type into the energy of operations continuously loses structural integrity. The operation of a machine is simultaneously the reason for its failure. Therefore an increase in entropy exists in an isolated system not only as a result of unavoidable dissipation of energy, but also as the result of the unavoidable degredation in the structures of the operating mechanisms. The state of maximum entropy in an isolated system indicates not only the transformation of all the system energy into heat, but also the transformation of all machines, i.e., of all the structured formations which operate in accordance with a program into randomly moving non-structured substances. There is no machine which can operate without increasing entropy as a result of a continuous loss of its structure. In the language of cybernetics structural machine loss is designated as "memory" loss. In applying the second law of thermodynamics to an existing active mechanism, i.e., to a machine operating irreversibly and in the form of continuous cycles, we come to the conclusion that after a specific number of operating cycles the machine will cease to operate due to sufficiently high losses in structure, or in "memory."

The fate of an operating machine is doom in the sense that the machine itself must, in a certain length of time, dissolve into a so-called chaotic medium. There is no machine which can extract programming instructions from its environment. A machine may withdraw only the components which it requires for the creation of new structural formations, including those programming devices which are included within it. However since the programming devices in a machine, beginning with the first operating cycle, enter into the disintegration phase and in a chaotic medium there are no replacements in the form of initial programming devices not affected by the degradation process, then it follows from this that no matter how improved are the programming devices with which the machine is equipped, it must inevitably become degraded and operate in a chaotic medium.

As shown above the concept of an operating mechanism or machine is a fundamental one. We shall attempt to find its empirical roots. During the pre-biological age on the earth various processes of the chemical synthesis of complex organic compounds occurred, but there is not a single phenomenon which indicates the existence during this age of any kind of continuously and cyclically operating mechanism with no connection with living systems. Cyclic processes on astrophysical, planetary and geophysical scales represent pulsation phenomena in the general flow of the transformation of energy leading to a small but irreversible increase in the entropy of a given system. These cyclic processes, not associated with living systems, can hardly be examined as the prototypes of cyclic processes of operating machines.

The well-known specialist in the theory of the behavior of complex systems St. Bier considers that "A machine intended for the accomplishment of certain functions is nothing more than a system with an organization which, from a specific point of view, is subject to the accomplishment of the problems placed before it."

"From a more general and physical point of view the machine and the living organism are similar," maintains philosopher E. Kol'man, "because they represent islands in an ocean of increasing entropy in all the macroprocesses in that part of the universe which we inhabit; these are islands where entropy decreases, for information accumulates..." The following idea was expressed by Academician A. I. Berg, "The processes of control occur in cybernetic systems which are characterized by an exact quantitative measure--a decrease in entropy."

On the other hand we have seen from an examination of the second law of thermodynamics that the machine is an unstable structure and its existence (continuous, irreversible, and cyclically occurring operations) becomes the reason for its destruction. In this manner we have discovered the following contradiction: 1) the machine, as a derivative of a living system, is always to a certain extent a model of a living system; 2, the machine, not being a living system, inevitably loses its structural integrity as a result of its existence.

In contrast to this, living systems are not only stable structures (under fixed environmental conditions), but in addition they possess the property of making their structure more complex to an unlimited degree and to perfect their functions. We have in mind not an individual living system, which is born, reproduces and dies, but an aggregate of living systems under the fixed conditions of a closed system. For example, this is apparent in orders of carnivorous and herbivorous animals and plants, which are ecologically associated; the mass of each of these living systems reveals regular fluctuations around a certain mean value, which is a constant with time.

We have reached the following conclusion: the physicochemical properties of a living system cannot fundamentally be modeled materially to the fullest extent, since the modeling mechanism is a machine which in general is a derivative of the living system and as such models this system to a certain extent, for a time and in a very close fashion, but it possesses a fundamental contradictory property which distinguishes it from the living system. This property is loss in the structural integrity of the modeling mechanism as a result of its existence.

The living system is an operating system. What distinguishes the living system from the non-living operating mechanism? We may point out four cardinal distinguishing features.

1. The structure of a living system at the temperature of its existence is labile, unstable and unbalanced.

2. The structure of a living system is maintained at the temperature of its existence due to operations which continuously eliminate

randomly occurring structural defects associated with the thermal destruction of the living system.

3. All operations in the living system are catalytic; the catalysts are the operating structures in the formation of the living system itself, i.e., complex proteins.

4. Due to the catalytic nature of operations in the living system, the transformation of the chemical energy of food substances to heat through operations occurs at the temperature of the existence of the living system. Under these temperature conditions the food substances are stable substances in the absence of catalysts.

These four cardinal properties, which characterize the living system as a thermodynamically closed system with specific properties, may serve as an illustration of the classical definition of life which was given in 1874 by Engels: "Life is a method for the existence of albuminous bodies, and this method of existence consists in essence of the constant self-renewal of the chemical components of the parts of these bodies."

Chemical reactions occur in the living system due to the high chemical potential of food substances and to the catalytic properties of the living system. Operations in the synthesis of the structure occur on the basis of chemical reactions which equalize random processes of the thermal destruction of the structure. Therefore the living system is a chemical machine, the work of which, on the one hand, is possible only at the temperature of the existence of the living system, and on the other hand, it consists of the constant elimination of structural defects which continuously and randomly arise at the life temperature. The dialectic law of unity and the struggle of opposites, in this case the presence of operations for the elimination of thermal destruction, when the operations themselves are possible only at the life temperature, form the internal contradiction of the existence of the living system; this is the basic property which distinguishes the "living machine" from the non-living.

We have pointed out above the thermodynamic difference between living systems and the derivatives of living systems, or machines. The acts of machines are inevitably accompanied by their structural degradation, whereas the aggregate of living systems possesses not only the property of preserving its mass during the course of replacement of generations, but also the property of continuing complexity and perfection of its morphological and physiological functions. To explain the origin, existence, reproduction and evolution of living systems within the framework of contemporary physical theories seems in our view to be impossible, since the objects which are investigated within the framework of these theories are always examined as an aggregate of spatially finite uniform phases.

A machine which models any function of a living system consists of a certain number of moving parts of finite dimensions. Each part represents a single (homogeneous) phase. The living system, in contrast to the mechanism which models it, is a system with unlimited "heterogeneity" (microheterogeneity). In order to describe the living system it is necessary to assume the presence of action factors which are associated with the infinite heterogeneity of the living system in the microstructure. In contrast to the non-living machine with moving parts of homogeneous phases, the moving components in the living system do not represent homogeneous phases. In order to describe the living system it is necessary to consider the presence of new parameters which appear during a study of the unlimited microheterogeneity of the structure of living matter. These new parameters are the specific factors of the unlimited microheterogeneity of a complex dynamic system.

At the present time the problem of the artificial creation of living material has become particularly important in connection with the creation of cybernetic devices which accomplish complex rational processes. Since a living organism is also a dynamic system which accomplishes complex rational functions, then a cybernetic machine, even though it performs only one of these functions, may be considered as something alive, in a certain conditional, lower order. The transition of a cybernetic device from a lower to a higher order is, however, principally unlimited in the sense of the accomplishment of functions of ever increasing quantity and complexity. In fact the cybernetic machine may accomplish processes of any degree of complexity if only the action realizable is expressed in the symbolic language of algorithms, which are deposited in the form of a program in the cybernetic machine. From this we conclude that from the point of view of cybernetics the difference between a living organism and a cybernetic device, which accomplishes the same function as the living organism, rests in the final analysis only in the history of their creation, rather than in a fundamental difference in physical conformities with law which control both systems.

The cyberneticist, therefore, has a right to maintain that the artificial creation of living material is possible in principle. In this connection we must keep in mind that a cybernetic device, especially constructed for the fulfillment of biological functions, fulfills these functions exactly as does the living organism and therefore according to the acknowledgement of the fulfillment of well-known biological functions there is no difference between living matter and a cybernetic device created from non-living matter. The functions fulfilled by the machine may be the most diverse, taken both from the medium of the physiological behavior of an animal organism, as well as from the intellectual activity of man.

We shall now examine the opposite, or anticybernetic position. The artificial creation of living matter in the form of a functionally creative cybernetic machine is impossible, since in principle the biological exchange of matter cannot be reproduced with the aid of non-living matter.

In approaching the problem of the artificial creation of living matter on the contemporary level of natural science, we must acknowledge that both assertions contradict each other and therefore they must contain mutually exclusive theoretical positions. The logical contradiction between cybernetics and anticybernetic assertions is eliminated, however, if we assume the following: living matter which possesses biological matter exchange cannot be created by any kind of artificial methods from non-living matter, but the diverse functions of the living organism which are the "derivative functions" of the biological exchange of matter, may be simulated as accurately as desired by cybernetic devices. If this position, which satisfies both the "cybernetic" as well as the "anticybernetic" assertions, is correct, then it simultaneously indicates the principal physical difference between the basic function of living matter--the biological exchange of matter--and all remaining functions of the metabolizing organism, which are arbitrarily called "derivative functions."

The thermodynamic essence of this physical difference between different functions of the living organism, if it does in fact exist, is encompassed by the following: those functions of the living organism which yield insofar as desired to exact simulation by cybernetic devices represent operations which do not contradict the second law of thermodynamics. They, i.e., the functions of the organism, which represent these operations, may be reproduced with any degree of accuracy by automatons, robots, and other cybernetic devices. However, insofar as the biological exchange of matter is concerned, i.e., that specific function of the living organism which lies at the basis of all of its diverse functions, this basic function of the living system represents an inherent, characteristic operation only for living matter; this contradicts the second law of thermodynamics. This process, since it does contradict the second law of thermodynamics, cannot be modeled materially. There exists, therefore, a thermodynamic prohibition--this is the impossibility of the material reproduction of the basic function of living matter--the biological exchange of matter.

No matter how complex the behavior of a living organism any observable functions which make up its behavior may be represented in the form of operations which in principle yield to simulation by cybernetic devices; here we even detect a certain superiority of the cybernetic device over the living organism. It proves to be the case that a cybernetic machine, in fulfilling any complex function of the organism, operates longer and more rapidly than the living organism. This functional superiority of the cybernetic machine over the organism is partially associated with the fact that the organism always fulfills a multiplicity of diverse, mutually related functions, whereas the specially developed cybernetic machine is free from "extraneous" functions. The superiority of the machine over the organism proved to be even more surprising when we arrived at the conclusion by theoretical means that it is possible to create a cybernetic device as a universal converter of information which is delivered to the machine in the form of appropriate signals.

The distinguishing features of the cybernetic device (the capability of modeling any complex biological function having the nature of an "external" operation, and the superiority of the cybernetic machine over the organism in the sense of the multiple repetition and rapidity of accomplishment of a given function) form the basis for the assertion that the activity of the organism supposedly represents the functioning of a mechanism which is subordinate in all of its parts to the same laws of physics and chemistry as any machine.

However the following fundamental difference with respect to the relationship of structure and functions exists between the living organism and the machine. The machine may also not operate, thus not wasting its structure during a time comparable with the time of the machine operating cycles. The machine possesses the stability of its structure at the temperature of its activity; the structure is also maintained when the machine is not operating. A living organism, on the other hand, must always function and if for some reason the organism ceases to accomplish its functions at the temperature of its vital activity then it irreversibly loses its structure and perishes. Since structural losses of the non-functioning organism are associated with a thermal variation in substances at the same temperature at which the vital activity of the organism occurs, structural maintenance in the vital organism must be associated with some kind of anti-fluctuation processes of the living matter apart from all the other operations of the active organism. In the organism the external operations and anti-fluctuation processes for the maintenance of the structure, while bearing the information content of the living system, are interlinked and take place at the same time and within a specific (narrow) temperature range in which the vital activity occurs.

We have established two fundamental, distinguishing properties of the living system.

First, at the vital activity temperature of the structure, the cells are thermolabile (thermally unstable) in connection with the crystalline, thermolabile structure of the intracellular water which is subject to continuous microphase transitions; crystal → liquid and liquid → → crystal.

Secondly, all nonaqueous components of the living cell (proteins, nucleic acids, etc.), which form with the water the structure of the cell, are carriers of information and in the presence of water possess thermal stability at the temperature of matter exchanged.

We have formulated the thermodynamic principle for the existence of living matter on the basis of these two fundamental properties of the living cell: *living matter is a dynamic structure which operates at the temperature of the thermal dissolution of its structure.*

It is impossible to create a dynamic system of non-living matter which would operate at the melting point of its structure. We may, therefore, formulate the following thermodynamic prohibition: it is impossible to create a machine, the function of which is encompassed in an inherent structure which is thermolabile at the active temperature of this machine. In fact, any "non-living" machine is subordinate in all parts and actions to the laws of physics for non-living nature.

The thermodynamic principle of the existence of living matter is an independent principle which indicates the independence of the physics of living matter and the impossibility of the origin of living[1] [Tr note--2-3 words missing] non-living matter known to us.

Two cardinal questions arise [Tr note--2-3 words missing].

1. Is it possible to create artificially [Tr note--2-3 words missing]?

2. How did living matter originate [Tr note--2-3 words missing] aspects?

At the present time it is impossible to give a decisive answer to the first question. Let us assume that in fact we will be successful in creating from non-living matter all of the non-aqueous components of the living cell--biomacromolecules (proteins, nucleic acids, etc.), i.e.,

[1]Part of the text is missing in the reproduced copy submitted for translation--Tr.

all the information components of a living system. Then the task of creating a living cell will be included in the assembling of all of these non-aqueous components which carry information in accordance with a specific plan compatible with the main component of the living cell, i.e., water. Since the intracellular water is in a quasicrystalline thermolabile state, the assembly of living cell components is possible only by two methods: either at an extremely low temperature in the presence of "frozen" (ordered, but thermolabile) water, or at the vital activity temperature, but without water, i.e., in a dry form. In the first case it is necessary to heat the system to the vital activity temperature so that the system may acquire biological matter exchanged; in the second case it is necessary to "moisten" the system.

Theoretically both methods are realizable. But in the experimental sense there are insurmountable difficulties. It is apparently impossible to make a structure of macromolecular components in the presence of crystalline water, i.e., at a low temperature when the macromolecular components are immobile; and it is also apparently impossible to make a structure of macromolecular components when water is not present, i.e., at the cell vital activity temperature, but in a dry state, when the macromolecular components are also immobile.

We shall now pass to the second cardinal question: in what manner did living matter originate as one of the material parts of existence if a thermodynamic prohibition exists against the origin of living matter from non-living matter which exists at the present time?

The analyses presented indicate the historicity of matter, both living and non-living. The world is material at all times. It is interesting to note that the age of living matter is of the same order as the age of the universe during the phase of its expansion.

The signs of the biosphere have been observed in deposits in the earth's crust withan antiquity of more than $2 \cdot 10^9$ years. Apparently the roots of life go back even considerably farther into the depths of time. It is believed that the age of the earth is equal to $3\text{-}4 \cdot 10^9$ years and the age of the stars is $5 \cdot 10^9$ years and that of the universe, $10 \cdot 10^{10}$. In the interval of time from 5 to 10 billion years ago the universe is believed to have been in a state of "primary chaos", the existence of which was controlled by those physical processes which were determined by the condition of the state of the material world of the time.

The conditions of the state of the universe changed several billion years ago. In this period of the existence of the universe the planet Earth originated and life grew upon it, apparently, similar to the thermodynamic phase which originated suddenly under quickly changing physical conditions during which time a given phase state existed. The generation of living matter is thus represented as the simultaneous origin of all the combinations of primary living substances under adequate conditions for their survival, and not as the birth of individual or several living substances, capable of unlimited reproduction. "From the geological and the geochemical point of view the question does not concern the synthesis of the individual organism, but the origin of the biosphere," wrote Vernadskiy.

The world of living matter and the world of non-living matter in the form in which they are known to us today have, therefore, approximately the same age, which is from 2 to 4 billion years. From this we may conclude that more than 4 billion years ago, when the universe began its present phase of development, i.e., the phase of expansion, two material substances (B) and (C), living and non-living matter, originated from a certain protomaterial (A):

$$\begin{array}{ll} & B \\ & \nearrow \\ A & \\ & \searrow \\ & C \end{array}$$

time $\rightarrow \infty$

and each of these developed according to its physical laws.

A LIVING BEING AND A TECHNICAL DEVICE

Academician E. Artobolevskiy and Dr. of Technical Sciences A. Kobrinskiy

One of the central questions raised in the article by Academician Kolomogorov is the possibility of creating an artificial living being. In discussing this problem, A. N. Kolomogrov expressed many interesting concepts, arguments and hypotheses which evoke a great deal of interest and a wide response from readers.

Of course it is natural that the article does not contain a direct answer to the question raised. Nevertheless the attitude of Academician Kolomogrov to the problem is rather clearly expressed by the following reasoning, cited at the conclusion of the first part of the article: "The fundamental possibility of creating valid living beings, constructed of discrete digital mechanisms for the processing of information and control, does not contradict the principles of the materialistic dialectic."

We consider it impossible to discuss the arguments of the author and his possible opponents until it is made clear what or, more correctly, who is understood by "valid living beings."

In addition, desiring to take a constructive part in the discussion of problems concerning the relationship between man and machine, we wish to fill in this gap by offering our formulation of the concept "valid living being." We shall warn that our formulation is partial, carries no quantitative appraisals and probably contains a number of other shortcomings. But since for the present other proposals are lacking, we shall consider it suitable for a first discussion.

We understand a "natural valid living being" as a being in particular who continuously grows and develops; who, as a one-year old, cries for unexplained reasons and soils his clothing; who at the age of three to five-years asks both wise and senseless questions; who at the age of fifteen gets school marks of twos and fives, becomes interested in verse and sometimes washes his neck without special reminders; who at the age of 20 works at a machine or in the field, passes examinations, or feeds a child; who at the age of 30 drives tractors and plans satellites; who during the course of his entire life is necessarily tied with thousands and thousands of other valid living beings; who at the end of his life dies, for the process of dying is still one of the unavoidable living processes.

We agree to acknowledge as living and valid such an *artificial* being which, while included in a society of similar *natural* valid living beings during the course of its entire life from birth to death is able to exist and act in accordance with the laws of this society with equal rights for all of its members, while working, moving, thinking and resting just as others work, move, think and rest.

If we agree with such a definition then it becomes difficult to detect in the article by Academician Kolomogorov arguments in favor of the fundamental possibility of artificially creating valid living beings.

It is possible, of course, to use the assertion that the cognitive power of a correctly organized human society is unlimited, that there is no meaning in compressing the region and capability of his creative activity in advance. But today this assertion is a generally accepted truth and it is hardly expeditious to dispute it during the discussion of each particular question which does not lead to specific arguments in a given case.

A completely different aspect is reflected by the question of whether to give the term valid living being to a technical device which fulfills at a certain rate some kind of logical or computer operations. Then the conformity with law of the discussion of the fundamental possibility of creating such a "valid living being" causes no doubts. However it remains unclear how far forward we will be pushed by this new pretentious label, which is pasted on a technical device which will possess one, two or several properties characteristic in fact of a living being, and which will probably surpass the living being with respect to these properties while it will not possess a countless number of other properties which in fact distinguish the living being from the technical device.

The expediency of such "desperately cybernetic" terminology, is, in our view, apparent because there still exist specific contradictions between purely logical structures and physical realizations, just as contradictions exist between fantasy and reality.

Let us turn to a simple example. Let an electronic machine control the fabrication of some kind of part on a machine tool under digital control. A sufficiently powerful computer may calculate the fabrication program with any degree of accuracy. In connection with this calculation each place after the decimal point, has, if we may so express it, profound significance for the computer. What about the machine tool? Only the first or second significant figure after the decimal point has any meaning (in machine construction dimensions are given in millimeters). For the machine the rest of the digits remain only numbers. Physical limitations (elastic and thermal deformation, gaps and clearances, tool wear, etc.) reduce to zero all attempts of the control device to force the machine tool to operate in accordance with the program calculated. In order for the control device to force the machine tool to perceive one more place after the decimal point, i.e., to operate with an accuracy of 1 micron, the control device must first be taught the theory of elasticity and dynamics, chemistry and physics and the methods of heat treatment and technological processes for the manufacture of the ultra-accurate parts of the machine tool. The control device must be taught design and this is quite difficult. To a certain extent design is an art, just as painting or sculpture. Stated briefly, even in connection with the solution of such a narrowly limited technical problem it comes out that the hypothetical control device must possess the capabilities and properties of a collective of valid living beings, broadly qualified, talented, work-loving, and creatively oriented toward their work.

In order to create such a machine it is necessary to explain to the designer the meaning of creative process, talent, thinking and to explain these not from a social point of view but rather so that the designer obtains specific quantitative concepts.

Are the scholars prepared to give the engineer the technical task, if not for the planning of a "valid living being," then only for the design of a "valid thinking machine?"

We find an indirect answer to this question in the article by the Academician Kolomogorov. His opinion relative to the level at which we find ourselves now in the field of the concept of mechanisms of thought may be judged from the example given in the second part of the article, where he attempts to trace the stages in the process of the formulation of the logical thought of a mathemetician, working on some kind of a problem.

"At first, *apparently* (the italics are ours--the authors), the desire to investigate a certain problem arises and then *some kind of approximate* concept is formed from an *unknown source* concerning what we hope to obtain as a result of searches and by what methods we will, *perhaps*, succeed in attaining this result and during the last stage we set in motion our internal "adding machine" of formal-logical reasoning."

Apparently the level of our concepts in the field of the thinking process and by the same token in the field of the mechanisms which lie at the basis of these processes is still extremely low. Therefore it is difficult for us to reconcile ourselves to the proposition, the essence of which is expressed correctly, in our opinion, in the premise, "In other words it is interesting to think about the creation of machines which, while not replacing man, will help him in the complex processes of creation."

Why is it difficult to reconcile ourselves to this proposition? In order to explain this we shall give an example from the field of technology.

A visionary once described a certain universal and fully adequate food product, synthesized by an industrial method.

Imagine food tablets which are small in size and which contain everything required to feed the organism, and which possess outstanding taste qualities and evoke sensations of pleasant fullness; in other words they fully satisfy the requirements of the most exacting consumer. Is it not true that the idea concerning the creation of such food tablets is extremely attractive? What quantity of labor they would save! How simplified it would be! Until the ends of their lives people would maintain small waistlines!...etc., etc.

Now we shall study this problem and as a first operating hypothesis in the direction of its solution we shall express the following statement: "At first, apparently, it is necessary to solve the problem of the chemical composition of this product and then settle how to form an *approximation* of the most suitable technological process for its manufacture; then we must put in the taste sensations from an *unknown source* which it must possess and finally, *it is not clear how and on whom* the products could be extensively tested."

And what if immediately after this preliminary hypothesis itself we should express the concept of developing an automaton which will manufacture food tablets from this product?

How shall we meet this proposition? We shall answer it in the following manner.

Of course work on an automaton represents specific interest in the light of the fact that the creative possibilities of man are inexhaustable and that sometime such a product will be created. But the main task now and later consists and will consist of solving and continuing to solve countless times the expressions "apparently," "somehow," "perhaps"...

It is these which are of the utmost importance and complexity and trouble many with their vital importance. And while no serious prospects for their solution have been indicated the possibility of creating a "valid thinking machine" remains just as fantastic as the possibility of creating a "valid living being."

There is still another question which we wish to touch upon, and that is the question of analogies.

We are completely convinced that "thinking" automatons of the future (we do not doubt that such automatons will be created) will "think" in a completely different manner than man does. However, if in the first stage of their creation the affair concerns automatons who necessarily must think "according to the image and likeness of man," then first of all it is necessary to understand how a man thinks and to understand the entire mechanism of thought as a whole! Specifically it is necessary to understand and not simply to agree that by thinking we mean this or that! Only when this thought mechanism is understood and explained to the engineer will the problem of the creation of a man-like thinking automaton stand on a solid foundation.

The more intensively man becomes acquainted with himself, the more the deep chasms of ignorance will be open before him, and the more man will contribute of his "man-likeness," utilizing this knowledge, to automatons; to be precise he will be able to indicate the difference between himself and his creation and, to get to the main point, the more essential these differences become. Such is the dialectic of cybernetics!

The mechanics of the Middle Ages and contemporary engineers, in studying working processes accomplished by man and in mechanizing and automating these processes, have become convinced on each occasion that the living organism and efficiently constructed machine or automaton fulfill these processes by acting completely differently. An aircraft does not fly like a bird, a steamship does not swim like a fish and a dough kneading machine does not knead dough like a baker; the first attempts to construct a locomotive "with legs" were unsuccessful...

Of course we can always find certain elements of similarity in the actions of a technical device and the living organism, and these similarities are broadly and usefully employed. But the more complex technological progress becomes, the fewer and fewer are these similarities; thus the gulf of the difference between the living organism and the technical device becomes increasingly apparent.

We are convinced of this by the entire history of the development of technology and it is hardly possible for the matter to change when humanity approaches in real earnest to the creation of "thinking" automatons.

As our knowledge of the thinking mechanism becomes more exact it will become clearer that insofar as technical (rather than natural) realization is concerned, this mechanism is of little suitability, that the functions which it performs are performed far better by a completely different design, and that the technological process of the "thinking" of an automaton must be completely different than the "technological process" of the thinking of a man: as the locomotive unavoidably had to be transferred "from legs" to wheels, so must the process of the creation of a "thinking" automaton be transferred from the head to the legs.

This means that in order to create a thinking automaton, knowing little of all of the details of the thinking mechanism of a valid living being, we must still develop or invent such forms of mechanisms which make these suitable for technical realization.

This amounts to a gigantic and perhaps even an incomparable amount of work if we consider the contemporary level of our knowledge and all of the characteristics of man as an object of the investigation!

We shall consider our established aim as achieved if the readers feel the distance which separates the automaton today from the valid living being, if they see the high level of development of science and technology already achieved, and in addition understand that the more that is done, the more remains to be done and finally if they learn to distinguish with greater certainty the desirable from the impossible and the imaginary from the real.

However there is evidence of the danger of propaganda from technical "clouding of the issue," where the developers of contemporary technology are condescendingly patted on the shoulder with the implication being that formulated ideas for "unusual" automatons already exist, which possess cybernetic (!) properties which fire the imagination.

Therefore it is quite important during broad discussions of technical problems to get as far away as possible from the position of technical "clouding of the issue."

THE MACHINE AS A PERSONALITY

S. Gansovskiy

The future abundance of "thinking" machines predicted by many scholars brings to life a question--will the time ever come when the necessity of disassembling one "intelligent" robot or another will place before man not only a technical but also an ethical problem? In other words will the disassembly of a machine somehow remind us of murder or in any case of punishment in accordance with the sentence of a certain scientific-technical court?

Since we apply ethical and moral criteria only to the personality (or to society which in turn consists of personalities), the question in essence is reduced to the following: "May a machine be a personality?" In addition, there are a number of other topics here. In the final analysis will not the "machine personality" become higher and more meaningful than the human personality, will the machines not be more clever than we and will we not have to examine under this assumption the possibility of the replacement of human civilization with machine civilization as an orderly, natural evolutionary step? In short, will the machine not force mankind from his cradle--the earth?

In all probability we have nothing to fear from this. We will not be ejected. And the day when the machine will have to examined as a personality is also not coming.

Why? In order to answer this question we must analyze what human personality is.

Human personality, in addition to the physiological aspects, has also a social and social-historical aspect. This is always the result of four biographies. In order to be a man, subject A must, first, repeat the phylogenesis (the history of the development and existence of a type of "intelligent man"), i.e., must have a body of human structure. Then it is necessary to fulfill his inherent physiological biography--to grow, and third, to be able to speak (i.e., to have contact with people) while not being detached from the thousand-year old human culture or from the culture, let us say, of his tribe. Fourth, it is necessary that he fulfill his social biography, to study something and to participate in the process of social life.

In connection with this, the further man goes from his wild forebears, the higher the value displayed by the latter two points, the social biographies, in his formation as a personality. In contemporary society we all are approximately identical as representatives of a biological form and different from each other first of all by our social position and social behavior. It is as if each of us stands on a high mountain which is formed by that which has been thought and accomplished by people before us and during our time. In any social decision we base ourselves first of all on our social and cultural experience, while not noticing this ourselves. If history is taken away from man and if people are separated from each other, humanity would immediately collapse.

Thus human intelligence and personality are formed by four biographies, of which the two latter, i.e., the social biographies, are especially important today.

What does a machine have to enable it to formulate a personality?

Here it stands in the laboratory--a huge block of billions of elements (and perhaps also of small elements, accomplished by means of microminiaturization). We shall assume that in capabilities it is the equal of our brain. But how shall we give it historical and personal social biographies? How do we teach it?

Some people believe that this is the simplest task of all. They believe that somehow the machine will learn easier than a man does and that in a month it would be possible to introduce into the machine a century's accumulation of human wisdom.

Well, let us test this. We shall introduce into the machine the novel "War and Peace." This can be done and the machine will then in fact "know" the novel, but only in an extremely narrow sense. It is in the sense that on the question, what lines follow the words: "...and this is again from the German. He will be in his place. And Deni"--it will give a decisive and rapid answer. But is this knowledge of a novel? Here Tolstoy begins to mean something for us only to the extent that what he has written is in keeping with our personal living experience. Natasha Rostova involves us only in view of the fact that we ourselves have lived through something similar to her dreams. And if this harmony does not exist, if to the reader the written marks and images are strange then even the most wonderful lines of Lermontov will have for him no greater meaning and emotional significance than $x + y = z$ under conditions that all three are unknown.

In other words, no matter how we teach the machine, no matter how many countless pages of scientific and artistic publications we introduce into the machine, this does not advance the work toward making the machine a personality by even one step.

Then what is to be done...social practice. We introduce the machines into the world as a member of a collective. But can the machine be included in social practice?

Here we have a laboratory. A machine is working here together with a group of colleagues. It sees, hears, moves and manipulates tools, it is present at all conversations and fixes these in its memory. Under these conditions is the machine equal to man and will conditions arise for personality formation? They will not. In order to perceive our social experience, which is included in art, science and morals, it is necessary to feel, perceive the world and in general to live like a man. The second signal system is generated and exists within us not of itself, but as a derivative of the first signal system, which depends on physiological specifications and on the electrochemistry of a specifically human organism, rather than some other organism. Of course reason is a function of the brain but this function is in the significance which forms the personality and also depends on what kinds of arms, legs, respiratory and circulatory systems we have. In order to be included in social practice the machine must breathe fresh air with pleasure, fetid air with aversion; it is necessary that the robots ear operate in the same range of oscillations, and that the eyes operate on the same wave scale. The machine must have a family, make friends, sympathize and be an object of human friendship, love or hate, which is possible only in a case where the machine is externally and functionally similar to man. We shall not, by the way, forget that the concept which we have discussed is not only a social one but is also historical and that the history of the development of every human personality, must, probably, begin from the moment of birth of human society on the earth.

Personality then is that which functions only in the process of the constant creation of self, in each given moment dying and being reborn, continuously representing itself as the end of one and the beginning of another stage not only in intrinsic physiological and social growth, but also in the development of the human genus and of society as a whole. Further, personality is inexhaustable and the answer to the question: "What am I?" can never be exact, since here there is a similarity with a well-known mathematical paradox: "How many numbers are there in the set of all numbers?" (No matter how this number is determined, the number of all numbers will be greater than any number obtained in the answer).

However the adherents of another view on the subject under discussion may ask us: "Well, what about it?" All this is true, but we could give the machine the same organs as Homo Sapiens. We will equip the machine with a stomach which prefers rare beefsteaks with a dry crust and with skin which is capable of perceiving the coolness of a spring breeze... If with the help of the proper genetic code we can create a biological robot which resembles man in everything, then what?"

Then our relations with such a being will pass outside the framework of the problem discussed. As far as the machines proper is concerned, which differs in some way from man, without a sufficiently stable, developed and uniform society of its own kind, it cannot become a personality and be an object of ethical relationship with our side. This is true because personality is meaningless without society, "I" does not exist without "we," "he" and "they." The possibility that man can create such a society independent of himself is for the present quite hypothetical.

One more question remains: can a machine surpass a man in intelligence? We must believe that in general it is not possible to mix the concepts "human intelligence" (which, obviously, does not exist without personality) and "machine intelligence."

If in agreement with Professor William Ashby we consider intelligence to be "the capability of accomplishing a suitable choice based on information received," then in connection with the solving of many narrow problems the machine has already left us far behind. But if we understand intelligence as the ability to combine in one whole, in a certain system, the elementary particle with the universe, and both with an unfamiliar face which appeared on the street; with musical accord and with the state of affairs in Southeast Asia; with the poetry of Pushkin and God knows what else; if we understand it as the ability to combine and evaluate the phenomena listed, and others, from the point of view of the interests of society, of which you yourself are the result; furthermore, if in being conscious of all these links we understand intelligence as the ability to discover paths for the improvement of the life of society, then according to such a definition the most clever machine passes, not only in comparison with the best minds of humanity, but also in comparison with the most unpretentious of its children.

By the act of placing man on the same footing with a machine, we already desocialize him and separate him from society. Cybernetics is powerful and a great deal is possible with it, but it is not possible to place a robot on the same footing with Homo Sapiens.

2. CYBERNETICS, WHAT PEOPLE THINK ABOUT IT.

FROM THE SPECTRUM OF CYBERNETICS

THE PHYSICS OF CYBERNETICS

Albert Dyukrok (France)

A New Scientific-Technical Revolution

Information is mainly associated in two aspects with the birth of industry.

From a practical point of view the results are tremendous and foreshadow the mass introduction of automation. Outstanding examples are already available: the complete automation of petroleum refining plants, blast furnace complexes, chemical factories and electrical stations, the work of which has been optimized by means of electronic devices. These devices are particularly widely employed to control contemporary atomic electrical stations. From the moment that machines obtained the capability of controlling themselves, the hope appeared that in the final analysis cybernetic devices would free man from any kind of work, beginning with the extraction of raw materials and ending with the distribution of manufactured products, provided, of course, that we could program them.

We shall emphasize, however, that technology in general will not imitate the human labor process. At the contemporary state of technology a machine is equipped with certain devices which permit it to accept only one category of information. This is the difference between the machine and man; he "sees" the external world, i.e., uses synthetic information incessantly, which permits him to reconstruct effectively a picture of the external world in his brain. It follows from this that a man in his active state is an extremely multi-contact entity. Just as a machine, a man is sluggish and uncertain, but he is distinguished by universality in contrast to the systematic specialization of the robot. Thus man is a real reflection of the world and remains in constant contact with it, while the robot is only a machine.

It would be Utopia to attempt, at the contemporary state of technology, to impart universality to a robot, similar to the universality of man. For example, in the process of sight approximately 140 billion cells are activated in our retina, but the information which is transmitted to the brain is encoded by a complex system of 15 billion neurons. If we even assume that a universal machine could be materially accomplished, its cost would so high that it would occur to no one at all to utilize it in place of a man.

The required limitation in the perception channels of robots leads to one important consequence of their employment in industry: in automating a factory, one cannot maintain its traditional structure; it must be transformed in order to reduce information obtained to a minimum. This leads to a change in the nature of the raw material, in the methods of processing or in the characteristics of the manufactured product. For these reasons the practical consequences of the introduction of automation will be much deeper than we usually assume.

Within the field of the intellect it is already possible to guess about the concept of cooperation which will arise between man and machine: man will occupy himself with the study of the surrounding world and will assign tasks to the machine which will then solve this; these are tasks which not very long ago were insoluble by man. From this point of view we can only guess very approximately the prospects of the cybernetic revolution, for in the past we could find no criteria for comparison. The history of progress to the present time has consisted of the fact that machines have been developed which have helped the work of our muscles. But the time is approaching when machines will help us to think.

Of course, this is already the philosophical side of the affair. It leads us to the conviction that cybernetics foreshadows the most intense transformation in the sense that it permits us to construct machines which are already capable of functions characteristic of living beings and, not unlike these beings, capable of organization, i.e., of negative entropy.

The Electronic Fox

Recently a diligent study was made of the problem of negative entropy, which arose due to machines. This was the main reason, cited as far back as 1953, for the development of an electronic fox, the behavior of which gave much valuable information. The affair concerned an artificial animal based on the same principles as the well known artificial dogs of Henri Piraux or the tortoises of Grey Walter.

However a new method was employed for the fox. This device fed itself with electricity and was set in motion by a system of motors. The fox had five sensory channels:

--tactile, which are excited when the fox encounters some kind of obstacle;

--a capacitive sense of smell, consisting of plates connected to the input of an oscillator circuit, the characteristics of which changed when the fox approached any kind of electrical current-conducting body;

--microphone;

--a pair of photo cells;

--a potentiometer, mounted on the body of the animal and imparting to it a sense of orientation.

According to the design each channel had its own capability of influencing a specific circuit--an electrical circuit which formed the "brain" of the animal. The circuit structure was changing at all times under the action of these influences, so that the behavior of the fox at any given moment was a function not only of a directly acting stimulant, but also the sum of all previously obtained stimulants, due to which the circuit acted as an integrating memory.

We shall add that we also introduced discontinuity in the perceptions and that the "animal" was capable of informing us of its internal development with the aid of a binary code, for which two electrical lamps were mounted on its head.

The development of the animal, left to itself, was quite characteristic. Observations revealed that after a certain length of time conditioned reflexes appeared; this means that the electrical circuit of the animal organized itself to correspond to a picture of the external world with which it was connected through the sensory channels.

The Birth of the Stars

Our attention must be attracted by still another fact. We construct cybernetic machines, however nature in this respect surpasses us by a great deal.

The organization of the cosmos is characteristic from this point of view. If we go back several billion years, and then imagine a picture of the "elementary" cosmos, it would probably consist only of a cloud of hydrogen. Under the influence of gravitation a cloud inside was broken up into parts, in which gravitation found a ground for new activity: it collected the hydrogen into gigantic spheres and their nuclear energy created stars. Thus arose "factories", where the matter of the universe was processed. The stars (they may remain in operation for billions of years) have dimensions which are automatically controlled, for in the process of formation these are determined by their mass. But this conditionality is duplicated again by a surprising thermal organization, the generation of "hot sources": in the black sky the surface of the stars release, like gigantic mountains, radiated light and heat.

In this matter the matter of the primitive cosmos entered into the work of the creation of structures which are the result of a play of the mechanisms of nature.

Here it is necessary to raise a question for ourselves which touched upon all the examples cited above: are not all of these forms of evolution in essence a refutation of the laws of thermodynamics?

It was only yesterday in physics that the formal principle of the "degradation of energy" was enforced, which not only denied every possibility of the spontaneous appearance of organization, but also involved the unavoidable constant increase in disorder in the world. Physics went so far as to describe the quantity of disorganization in an isolated system, i.e., in a system where the entropy could not be reduced. How under these conditions are we to understand the natural and automatic process of the organization of the universe, which we may imagine purely on the basis of physical mechanisms?

We had the opportunity of thinking about this contradiction, all the more so since cybernetic technology was successful in proving that this law of fatal disorder had never been proved. The electronic fox reduced its entropy while not changing the medium in which it developed. This means that the total entropy was reduced in the isolated system which comprised the fox and its environment.

Our conclusion was clear: it is necessary to refute the old concept of entropy and it is necessary to analyze the hypothesis and conclusions of physics which have raised the philosophy of disorder to the level of a universal law.

This philosophy arose on the basis of thermodynamics and science, and was considered a tremendous scientific achievement of the XIXth Century. But cybernetics permitted us to understand that thermodynamics is not a universal science. It is the physics of special systems, formulated, as we shall see, by tracing in detail the development of thermodynamics, its laws with the aid of entropy, but relegating to the background the description of systems of other classes, not amenable to proof with the aid of its conclusions. Only cybernetic physics can tell us about the systems.

The principles of such a division are clarified during the detailed description of the development of themodynamics while the consequences which flow from this give us a key to the understanding of the history of the universe.

The Process of Entropy

The birth of the philosophy of disorder was caused in the last century by the development of thermodynamics, which arose at a time when physics began to investigate mechanical work in heat.

The new science very quickly evoked furious disputes. Physicists found that a body weighing 3 t, falling from a height of 1 m, releases 7,000 cal, which is sufficient to raise the temperature of 1 l of water from 8 to 15°C. It was very tempting to conduct the reverse operation, i.e., to take as "raw material" 1 l of water at 15°C, to obtain from it 7,000 cal and thereby raise a mass of 3 t to a height of 1 m or to accomplish some other equivalent mechanical work. The "remainder" after the operation was 1 l of water at 8°C.

But this is a chimera--or the immediate comment of the heat specialist; they looked very mistrustfully upon the possibility of accomplishing such a process and from the very beginning considered that it was too good to be true. In fact, 1 l of water at 15°C contains potentially 7,000 cal more than 1 l of water at 8°C. But physicists have ascertained that if the environment has a temperature of 15°C then these 7,000 cal cannot themselves be released from the water and thus lower its temperature to 8°C. Clasius says that in an isolated system no quantity of heat can be transferred from one body to another which has a higher temperature, and in general temperature differentials cannot appear themselves without outside assistance.

We are forced to agree with this. There must be a temperature differential in any thermal machine, since mechanical energy cannot be obtained other than by black body radiation from the source of heat: a certain part of this will be absorbed by a cold machine and only the difference will be transformed into heat. Thus the theoretical equivalent of heat and work obtains the characteristic of irreversibility.

The Concept of Irreversibility

In 1865 Clasius introduced the concept of entropy in order to make it possible to calculate this thermal energy value. It became a nightmare for many generations of students and a bone of contention for physicists.

What is entropy? The term comes from the Greek entrope and means "to close inside." And since it has been applied by Clasius it also means the measure of degradation of any kind of system. The physicist defines entropy as the ratio between the quantity of heat and absolute temperature. If we examine the problem of effectiveness more closely then we shall grasp the meaning of entropy: under optimal conditions all energy transformations occur on the basis of constant entropy.

If, for example, a thermal machine is arranged with a source of heat at 600°K which furnishes 1200 cal, the entropy deviation will equal -2. Clasius maintains that the work of the machine will be optimum if a cold source will have an entropy deviation equal to +2. In other words if the cold source has a temperature of 350°K then it is necessary to add to it 700 cal. Only 500 cal is transformed into mechanical work. This at least is the maximum effectiveness; in actual fact the machine will operate under less favorable conditions so that the cold source will be given 800-900 cal. In this case the entropy of the system will increase.

Thus the entropy must increase everywhere where the thermal machines operate with an efficiency less than the theoretical value while the transformation of mechanical energy into heat must, from the point of view of quality, be a pure loss, which appears as a sharp increase in entropy.

This is a convenient explanation. But is it satisfactory? Does the concept of entropy have a physical meaning or is it only a mathematical construction?

Entropy and the second law of thermodynamics, frequently called "the entropy principle", in fact was employed at the beginning very strictly. But soon the kinetic theory of gases made clear the connection between heat and mechanical energy and this helped us to understand the role of absolute temperature in Carnot's principle and in the entropy of Clasius.

As is known, gas molecules are in motion with an average velocity which is characteristic for each given temperature. Strictly speaking the energy of the molecules is proportional to the absolute temperature, so that the transformation of heat into work is only a change of form: from a state of disorder, energy clusters are transformed into a state of marching order. This means that temperature is mechanical work dispersed at the molecular level.

The concept of the transformation of work into heat appears directly from the course of the process itself; we shall understand also why such a transformation proves to be irreversible: the molecules are not individual ones which choose for themselves a direction according to their will, but are material particles which do not enter into any kind of order; in other words, returning from disorder to order is not possible for them. Accidently of course it is impossible that all molecules at a given specific moment may be in motion in the same direction; then the thermal energy again would be transformed into mechanical energy. But a simple calculation shows that the probability of a similar phenomenon is too small to keep in mind.

Such were the conclusions which physicists gradually arrived at during the second half of the XIXth Century. Physicists understood that heat and work were equivalent only quantitatively, rather than qualitatively, since "innate" disorder is characteristic of heat while an object in motion, where all points are in motion identically, is characterized by order.

Order and Disorder

We shall remind ourselves that disorder in itself should not be considered to be more probable than order, since the evaluation in these terms is purely subjective. But for thermodynamics all the difference consists of the fact that in the one case, which is characterized by order, we find billions and billions of other cases under the sign of disorder. Always, therefore, when we are dealing with a system which is "left to itself" (for example, a gas, the molecules of which are distributed at random and all cases are identically probable), there is only one chance for order while there is an uncounted number of chances for disorder. The conclusion of the probability calculation is formally faultless.

If each structure, realized by any state, is called a component, then the general direction which permits a system to shift may be represented as an individual case which is realized by the minimum number of components, whereas the huge anonymous group of cases of thermal motion will consist of billions of various components. Boltzmann discovered for the entropy of Clasius a special physical meaning: he proves that entropy is measured by a logarithmic number of components which pertain to a specific state.

The Danger of Generalization

The new concept of entropy may be significantly broadened.

May we not apply the description based on the calculation of components to any state of matter? We become witnesses to the generalization that we are beginning to express the development of all systems in terms of entropy.

Physicists maintain that the entropy of their isolated systems may only either remain constant or increase. Each "factual change", as expressed by one of the most outstanding physicists, facilitates an increase in entropy, while if the system is left to itself it will have a tendency to degrade and its development will pass from order to disorder.

In addition, the idea arises that as a result of a bold generalization the entire cosmos (in fact, with what or with whom could it enter into an exchange!), may be considered as an isolated system, and therefore its entropy must continually increase so that each irreversible phenomenon, i.e., each evolution, increases the entropy of the cosmos.

This is how the picture of the systematic degradation of the universe appears. In a philosophical sense this picture expresses a concept dear to each man. In fact, instinctively man has always wanted to see a grandiose development in the history of the universe, when at first only a certain order was given, while all history passed to the side of disorder.

This intuitive concept was consecrated by science with its dogma concerning the undeviating increase in entropy and forced the physicists to see in the development of the universe a number of events which systematically destroys initial order. This means that *the initial, basic state was considered to be a highly organized one*, which in subsequent development was unceasingly disrupted; only living beings appeared to be special exceptions who are capable of creating negative entropy, locally and for a short period of time. It would seem that in this respect our physicists had nothing to object to. To culminate all, on earth scales everyday experience proves their rightness. We never observed that any substance could spontaneously divide into two parts with different temperatures, and we never saw a heat machine operate without a source of heat.

Is not natural degradation a tragic law of nature? Everywhere around man metal is covered with rust, matter decays, the wonderful creations of nature and technology disintegrate, time brings wounds and disorder, works for disintegration, and not for creation. Notwithstanding all this, we find in these classical discussions one great error. *All* examples on which physicists base their conclusions concerning entropy, possess one common characteristic: the case always concerns "anarchic" systems.

Under terrestrial conditions gas in a vessel consists of molecules which are not subject to the influence of external conditions. Physicists hypothetically liken the molecules to globules upon which, while they are in the vessel, gravity has no influence. These globules are in motion under conditions which exclude any kind of atomic forces (incidently, in the XIXth Century atomic forces were completely unknown). It is further assumed that these molecules possess a constant structure, that they are electrically neutral and that they are repelled from the sides of the vessel and from each other, like simple globules. The components in this case do not depend upon environment; collisions, which are assumed to be completely elastic, insure completely random molecule distribution.

Under these conditions, which in the physical sense gives an improved picture of the anarchic system, an ordered structure is only a separate case in comparison with the astronomical number of other cases for which disorder is characteristic. And since each of the cases is of identical probable realization in the process of molecular motion, order cannot arise spontaneously.

Such a conclusion is reached because the system is anarchic. To speak of entropy under such conditions would be simply tautology; for a physicist entropy means only that the components of a system are arranged randomly. This is the result of a hypothesis which he silently accepts.

It would seem that these hypotheses are well confirmed by the example of a gas which is in a vessel under terrestrial conditions. But can we not a priori imagine other conditions which differ from this case? If we are dealing with plasma, particle motion within it cannot be considered as random, since it is controlled by an electrical field. On a cosmic scale neutral gas particles also have a specific direction, since gravity acts on them. In other words, the language of entropy has meaning for hypotheses which in fact relate *only to an ideal case*. It seems almost unbelievable that for almost the entire century physicists have not pointed out this fact, since it is a fundamental one.

Maxwell's Demon

Here it is necessary to raise the question: what will happen if the components of any system become the objects of selection?

The physicist Maxwell was disturbed by this problem as early as the last century. Untiringly Maxwell worked on the problem which he was not able to solve and which for a long time has been known under the name of 'Maxwell's demon."

The great physicist postulated two identical, closed chambers, filled with air and connected with a channel through which air could pass freely. Probability calculations indicated that the same quantity of molecules would pass in both directions per second. Let us now imagine that the connecting channel is extremely narrow and that it may be closed with a small door, the control of which has been entrusted to a small, dexterous demon: he opens the door when a molecule is traveling from right to left and closes it against a molecule which is traveling from left to right. As a result of such manipulation the pressure in the left chamber will continue to increase, and since the opening and closing of the door theoretically requires the expenditure of no energy, then asymmetry, i.e., negative entropy, appears.

Here only one condition is necessary; the molecules must be forced to act differently, depending on their direction of motion.

We find such selection behavior on a cosmic scale, where gravitation plays the role of the concentrating factor, *which directs hydrogen to those regions where it has begun to accumulate in random fashion.* Then asymmetry, which we call disorder, ceases to be random and becomes a state which the system approaches; then all the concepts of probability lose meaning, since we are dealing with a system of evolution which proceeds not randomly, but conditionally.

The Phenomenon of Feedback

The birth of stars or galaxies is very important from a logical point of view. If we are dealing with interrelated systems, then here, on the very threshold of space history the tenet of disorder is refuted in a remarkable manner; simultaneously we obtain a remarkable illustration of what may be called consequence No. 1, i.e., positive feedback.

From the moment when a specific quantity of hydrogen is accumulated at a certain point in space, it confines matter which is diffused in the vicinity; the mass increases, the force of gravity increases, and as a result it attracts more and more. Here we see positive feedback, i.e., as shown by the name, a picture in which the consequence produces the cause. From this moment all laws of randomness are thrust aside and the process feeds itself with an ever-increasing sweep; development becomes unavoidable.

The process began on the scale of a galaxy or a star, and feedback continues to expand. The remarkable fact here is that in connection with positive feedback the source of conditionality is not something external. This remark has fundamental importance. A physicist who desires to describe the universe attempts to find a language which remains valid for any selected code of relationships and which does not express the impressions of the observer, but the laws of nature. Such was the sense of the work accomplished in science by Einstein.

In describing the phenomena, we must consider feedback to be the basic process of development; it arises in a system which operates in a short circuit. With positive feedback conditionality is generated "by itself".

Still another consideration arises. As a result of exponential increase the value which is controlled by the positive feedback process will attain fantastic dimensions so that the process will not continue further. Its development changed the base of the problem itself in a meaningful way.

Here it is necessary to make note of two statements. Positive feedback is a source of organization, but at the same time its very nature prevents it from *ceasing independently*. It will cease to act only...

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...releases the substance; thus it loses a significant part of its mass which in the final analysis is reduced insofar as the process ceases to play a significant role. Is this not a space version of the speed regulator invented by Watt in the XIXth Century?

In Watt's device two rods with two balls suspended from them were mounted on a vertical shaft, which obtained its motion from a steam engine. Under the influence of centrifugal force the balls moved away from each other, and by this action set a ring into motion, which controlled a slide valve; the slide valve in turn controlled machine motion. If under these conditions an accidental or random decrease in speed occurred, the device automatically increased its activity, and vice versa.

A similar idea is at the foundation of contemporary technical versions of industrial regulators, in which an electric motor is controlled by the indications of a tachometer machine-generator, which functions as a speed sensor. It is thus possible to maintain a constant speed at any load; with an increase in load the machine-generator increases the power output of the engine. The reverse is also true; if the engine is idling the machine generator reduces the strength of the current and slows down the speed.

In general technology creates devices with feedback everywhere where automatic regulations require, for example, for the control of pressure in a tank: a comparator determines the difference between the pressure indicated by a sensor and the required value. Depending on the value of this deviation, it takes corresponding action. If the pressure is too low it sets in motion an electric motor in order to raise it; if the pressure is too high it opens a valve. Was not the release of matter by the stars a prototype of this function?

On the other hand, technology at the present time knows that if a system controlled by a feedback circuit reacts too intensively, the control value may obtain a deviation to the opposite side, and this again causes an opposite reaction. Thus the phenomenon arises which is called self oscillations and which progresses in an oscillatory mode. We find this phenomenon on a cosmic scale in the well-known category of variable stars.

Overall System Logic

These are the signs of the intellectual revolution which cybernetics has carried with it. The heroic age of cybernetics, i.e., before 1955, was characterized by antagonism between cybernetics and physics. For many physicists cybernetics was only a new science which had to be placed within classical frameworks and from the very beginning even in this the principle of entropy was applied. Such a point of view led even to a certain variant of the degradation of energy--to the degradation of information. This absurdity is thrown at us: if a certain integer exists in which it is possible to note an "increase in quantity", then this itself is information.

In fact, cybernetics was situated not *among* the classical sciences and technology, but *above them*, since it gave logical criteria for the overall study of systems of which classical thermodynamics explained only one field, namely, the principle of entropy, which refers to isolated systems *without internal conditionality*. Those systems which became the subject of study of thermodynamics were called "ideal."

Apparently this term was a euphemism. Ideal systems are those in which laws established by physicists are fully valid. Substances which obey the law PV = RT are called "ideal gases"; this law assumes that between the molecules, the masses of which are mass points, there are no interrelations.

If we investigate the hierarchy of organized systems we shall see that systems which are called ideal prove to be those systems left to anarchy; the law of entropy was the law of this anarchy.

Thus we may define the field of thermodynamics: it includes systems which consist of "independent" components.

If we come out of this state of zero organization then before us the problem is raised of the creation of the physics of organized systems.

If we make more exact the bases of the overall hierarchy of structures, then we shall see that classical thermodynamics serves as its foundation and organized systems which have created the development of life are situated at the summit of thermodynamics. The content of cybernetic physics must be an exhaustive panorama of structures--just as until recent times the basic problem of chemistry was the compilation of the complete table of elements--as well as an approach to their synthesis with the help of technical methods.

CYBERNETICS--THE ART OF CONTROL

Professor Lui Kuffin'yal' (France)

Why is Cybernetics an Art?

Cybernetics Studies Action

According to Wiener's definition, cybernetics studies control by machines and by living organisms. Examples given by Wiener himself reveal that the sphere of activity of cybernetics encompasses both the aggregate of separate parts which form the machine as well as the aggregate of individual organs which the living organism presents as a whole, or the aggregate of living organisms consisting of a society of animals or people.

What is observed in common in such diverse objects--that which permits the development of a single theory of control for them? The single common characteristic is the fact that all of these objects act on each other and that the concept of control pertains only to action and to nothing else. It is possible to control the actions of one man or a group of people; the nerves control the action of the muscles; the cams of a lathe control the action of the cutter which processes the billet. Therefore cybernetics studies the action of certain objects on others whether they are living beings or machines created by man.

What is Action?

Even a short investigation of any kind of action indicates that the logical operations controlling it fall into specific categories.

Action is accomplished by the *performer*, while the objects of action with respect to the performer are included in the environment. For example, a brigade of bricklayers, which is engaged in building a brick wall, is the performer of the action, which consists of placing some bricks on other bricks and cementing them with a suitable mixture. The bricks, the mixture, tools and the place where the wall is being built represent the external environment which is subject to the action of the brigade of bricklayers.

The action has a specific purpose which consists of transforming the environment into a certain new state.

The action develops with time. It begins at a specific *initial moment* in time and is also concluded at a specific *final moment*. At the initial moment the environment is situated in a certain initial state and at the final moment the environment is in the new, final state. The action is considered to be effective if the final state of the environment corresponds to the purpose.

In the preceding example the naked earth represents the initial state of the environment. The purpose includes the erection on the earth of a wall which is a new state of the environment; the action is reduced to the furnishing of bricks, mixture, tools and to the laying of the wall; the land with the wall erected on it is the final state of the environment. If a complex wall corresponds to the design of the architect, i.e., if the purpose of the action is achieved, then the action is considered to be effective.

The Control of Action

Therefore the basis for evaluating an action lies in its effectiveness.

Any action is always undertaken under the assumption that it will be effective. For this reason *preparation* for the action is included in the development of its *program.*

For example, drawings of a machine and each of its parts are developed in a design bureau. The types of production operations and their sequences are defined in the technological division. In the workshop decisions are made regarding when each operation will be accomplished and which machines will process certain parts, as well as which workers will manufacture individual parts. All the decisions formulated are recorded and the appropriate documents make up the production program for the machine.

Here are other examples. The commander of an army establishes a program of action for his troops; the development of the economy of the country is accomplished in agreement with a program, which in this case is called a plan.

Action is begun in accordance with a plan developed in advance. But often circumstances lead to the fact that it is necessary to change the program in the process of its accomplishment or, as required by circumstances, to replace the program with a new one at a time specified. This is also control of action.

The control of action is required due to the reaction of the environment.

Environmental Reaction

The fact is that the environment, which is transformed in the process of action, in most cases reacts to the changes produced in it and this reaction may be most diverse, depending on the nature and character of the action.

Environmental reactions may be divided into three basic groups.

a) *The reaction is the same as that predicted in the program.*

The example cited above concerning the erection of a wall belongs to this category; the ground offered no opposition to building the wall. In this case environmental reaction is passive. In this case it is possible to fix the sequence of operations in advance, which in all probability will lead to the purpose established.

b) *The reaction cannot be predicted, but it runs in accordance with known laws which associate it with the action of performance organs.*

For example, the purpose of the action of a system of regulation for central heating includes the maintenance of a constant temperature in a room. The temperature of the room depends on the temperature of the water in the radiators, which in turn depends on the degree of opening of the air duct, through which air enters the furnace. The air delivery valve is the performance organ of the system of temperature regulation. The reaction of the environment consists of the fact that the temperature in the room depends on the temperature of the surrounding air, on how many windows are open, on the number of people which are located in the room, etc.

All these factors cannot be predicted in advance. In general it is possible only to evaluate their influence, the result of which is the real temperature of the room. However the relationship between the temperature of the room and the position of the air delivery valve is known: if the temperature in the room is reduced, the air duct must be opened wider, while if the temperature increases, the air delivery decreases.

Under such conditions it is said that the reaction of the environment is deterministic. Here it is not possible to establish in advance a sequence of operations which would lead to the purpose indicated; it is possible only to indicate a method of action which must be adhered to by the executive agents under certain circumstances.

c) *The environmental reaction cannot be predicted and the relationship between the environment and the performing organ is unknown.*

The catching of butterflies may serve as an example: a man steals up to a sitting immovable insect, but at the moment when he plans to catch it with a net the butterfly flies off to another flower.

In this case we say that *the reaction of the environment is random.*

There are very many examples of the third category of environmental reactions. In most cases the effect of one man on another or of a man on living organisms belongs to this category. Such are the actions of the army commander, of the developer of an economic plan, and of the head of the state.

Since it is possible to develop neither a program nor a method of action which will permit with certainty the achievement of the established aim, the performer at each moment must select that action which more than any other will place him closer to his target. It is essential that control over the action be exercised by the commander, who is informed at any given moment of the situation as it develops and who makes decisions and issues commands to accomplish the required operation. Here the *art of control* appears which the commander possesses. In the same sense we speak of the art of the engineer and of the ocean navigator.

Thus the management of activity, the variety of which comprises control as examined by N. Wiener, makes up one form of thought which is accompanied by action and which is understandable in a wider sense than the "theory" of control. The term "cybernetics" also refers to this form of thought.

In expanding the significance of this term even further, we arrive at a definition which was given, at my suggestion, at the time of the first International Congress on Cybernetics in the city of Namur (1956), *"Cybernetics is the art of effective action."*

Cybernetic Logic

Ordinarily the intellectual activity of man is divided into literary, scientific and technical activity. Cybernetics creates a new form of intellectual activity, and the interrelations of this activity with the types of activity enumerated above must be strictly defined. From a comparison of cybernetic logic with the discussion method of the scholar, the activity of the technician or of the writer, it followed that this "art" is of a completely different type.

Science, Technology and Cybernetics

Cybernetic logic differs from scientific thought by the following characteristics:

In connection with the behavior of bodies science is occupied with detecting the laws which describe the interrelations of these bodies, whereas cybernetics develops programs of actions;

Scientific laws aspire to the closest generalizations and do not consider certain absurd phenomena to which known laws are not applicable at a given moment; cybernetics, in developing a program of effective action, deals only with the limited field of the environment, but in this connection must take into consideration all known properties of this environment, including those which are not considered in the establishment of scientific laws; science occupies itself with that which is past and that which is real and often refrains from conclusions concerning the future, whereas cybernetics must predict the future and is based on the final aim of action; its task includes the selection of methods which will permit the achievement of aims which are established before the action commences.

The differences listed also show that cybernetics is not an "applied science."

Attempts have been made to identify cybernetics with the science of behavior. George P. Bulanzhe even limited the field of cybernetics to purposeful behavior. But in the science of behavior, even of purposeful behavior, one observed action *is explained* as the consequence of another action, whereas cybernetics *selects* the action for the achievement of a specific purpose. Plato wittily investigated the actions of the helmsman, closely associated with the actions of the captain and the rudder. The rudder affects the helm, and its action has a final purpose. But the helmsman himself controls the actions of the rudder so that the ship reaches port and the thought of the helmsman is cybernetic thought. The purpose of the action is determined by the captain, who issues the commands.

The thought of the helmsman represents an example of cybernetic thought and the word "cybernetics" is derived from the ancient Greek word κυβερνητικη, which means "helmsman."

Cybernetics does not pertain to a field of technology, as it does to the fields of science. It does not represent a certain technical theory which is comparable, for example, with the theory of turboengines, which describes the general relationships between the action of the turbines, pumps, fans and other similar machines.

In fact, the technological process is reduced to the application of a program while cybernetics develops the program itself and changes it depending on environmental reaction.

Thus cybernetics, while differing simultaneously from both science and technology, is characterized by a special method of thought.

Cybernetic logic is complex and all of its forms have not yet been fully studied. However at the present time the method of analogies and models is already employed widely and it is thus possible first to give a scientific survey of them.

Mechanisms, Analogies and Models

It has already been pointed out above that action develops with time and that as a result of action the environment changes. This phenomenon may be expressed exactly by means of the concept "Mechanism."

A mechanism is a physical system which may change its state in sequence. For example a motor vehicle engine consists of parts which occupy in the course of its operation a number of various sequential positions. The engine is a mechanism. Chemical substances which interreact and which change with time also represent mechanisms. In the same sense we speak of the mechanism of a chemical reaction, about the economic mechanism, and about the mechanism of mathematical proof.

Several other simple concepts are associated with the concept of mechanism.

A mechanism is termed *formalized*, if its relationships with the environment are known in advance. A formalized mechanism obtains basic *data* through *an input device, processes* them at the *input* and issues *results*. The action of the mechanism is determined by the local relationship between the initial data and the results; the *structure* of the mechanism depends on the nature of its organs and the method of their *action*.

The difference between action and structure of the mechanism is quite significant: action is based on the fact that mechanisms having a different structure may accomplish the same action, while the same mechanism may accomplish several different actions.

As a first example, in order to heat a kettle containing water it is possible to employ any such mechanisms as an ordinary stove, a gas stove or an electrical plate. As a second example, the most obvious action of the muscles of the human body consists of the fact that they set into motion the skeletal bones, but they also have a less obvious function, consisting of the accumulation of glucose.

Two mechanisms are similar if their corresponding organs accomplish the same function. For example, a phonograph disk and magnetic recorder tape are similar mechanisms since their functions consist of the preservation of a musical recording.

The analogy concept is widely employed; in the process of thought everyone resorts to analogies and comparisons. However, as we showed earlier, cybernetics cannot be satisfied with the method of scientific thought, i.e., deductive thought, but must analyze the judgments which it has utilized and the conditions of their effectiveness. For this reason the substance and method of analogy have been studied.

The analogy method consists of the following: *Having become convinced of the similarity of two mechanisms* (i.e., due to the fact that they fulfill certain common functions), *we assume that known functions of one mechanism are also characteristic of the other mechanism, for which their presence has not been established.*

For example, we have observed that the functions of animal organisms, such as feeding, respiration, blood circulation, elimination, etc., are similar to the functions of the human organism and that the performance of these functions may be disrupted by the same illnesses. In the study of the action of a medicinal preparation we first carry out tests on animals and then assume that in designating this medicine for man the results will be similar to the results obtained for animals. The approximate dosages of medicine for man are determined in this manner.

An artificially created mechanism which has specific analogies with a given mechanism is called a model of a certain mechanism or action.

We shall now return to the preceding example.

Before animal tests are begun, the microbes of a specific disease are cultured in a nourishing medium which represents a model of the humoral medium of the living organism. Both the nourishing mediums and the animal organisms represent analogies of the human organism, but the nourishing mediums are prepared by man and therefore are models; the animal organism cannot be created by man and represents a natural analog of the human organism.

It becomes clear from the definition and from the example given above that the development of models is closely associated with the method of thought by analogy. The progress of man in the knowledge of the surrounding world and in his effect on the surrounding world has occurred due to the development of models to which the method of thought by analogy has been applied.

One of the most remarkable consequences of the results of studying the method of thought by analogy has been the development of conditions required so that a higher probability of model effectiveness would occur:

The model must be correct, i.e., it must be analogous to the original;

The model must reproduce the principal functions of the original, rather than its structure;

The model must be simple.

For example, a vector serves as an ordinary force model. This is a correct model because such characteristics as the origin of the vector, its direction and length are analogous to force properties: to the point of application, direction, and magnitude. Therefore in most problems the dynamics of force may be represented by a vector model with a great probability that the solutions obtained during operations with vectors will be confirmed by experiment. We note, however, that the French investigators Pol' Penleve and Et'yen Dellassyu cited examples of existing real systems, the behavior of which cannot be described by means of the application of the laws of dynamics to their vector model. In 1951 Norbert Wiener at the Paris Congress "Computers and Human Thought", pointed out the similarity between closed circuits of the nervous system and the closed electrical circuits of computers, in which the pulses act for as long as required while forming the "memory" of the machine. Such a similarity permitted us to think that the closed circuits of the nerves represented the memory elements of the brain. However another participant in the Congress, Lorente de No, revealed that this was not the analogy noted by Wiener, since it was based only on a structural similarity of circuits and it proved to be ineffective.

Below, in the section "Population Reaction to Psychological Influence", we shall relate similarities between the circuits indicated, which are based on functional similarities and which have proved to be quite effective.

Mathematical models predominate in theories which state those changes to which certain models may be subordinated by means of employing the rules of logic. The development of a great part of theories at a specific stage has ceased and more attentive study has revealed that this moment arrives when the models become so complex that the human mind can no longer encompass them. Thus the theory of algebraic curves, which has been worked out in detail for curves of the second order, in relation to curves of the third order in the best case is limited by the classification of their forms, while a study of curves of higher orders is reduced to an examination of individual particular cases.

Information

Just as steel serves as the material for mechanical constructions, information is the material for thought. N. Wiener presented clearly the tremendous significance of information by combining in his definition of cybernetics such concepts as "Control" and "Communication", i.e., the transmission of information.

Several theories of information have been developed, of which the most well known is the theory of C. Shannon. But cybernetics in the wide concept which we accept must reflect those circumstances which are reflected by different theories of information.

Using ordinary curves, we may define information as "A physical influence which causes a responsive physiological action."

This definition must be clarified for the effective use of information with the aim of controlling action.

In his bold comparison Grey Walter examined psychological actions as the transmission of physiological functions. He termed the functions of *thought* as the reception, storage and processing of information. The psychological actions of perception, memory and imagination correspond to the receipt, storage and processing of information. It is also convenient to isolate the function of the will which appears in taking certain positions which represent one of the varieties of information.

Thinking is analogous to the assimilation of food. Overcooking food has a similarity with perception, since during cooking the food is transformed into chemical substances such as glycogen and glucose which may be stored in the tissues of the organism. Memory has similarities with the glycogen activity of the liver and of the muscles, which accumulate and store the energy derived from food.

Finally, imagination is analogous to that function of the organism which creates one or another physicochemical energy carrier which corresponds to a method of the utilization of this energy in a certain organ of a living being. Briefly analogies between the assimilation of food and thought consists of the fact that in the first case the human organism receives from without, stores, changes the form of and distributes the energy which it requires and in the second case, in the process of thought, the analogous operations are accomplished with respect to information.

The "thought" concept is associated with one peculiarity. *The organ of thought* is not known to us, just as the organs of memory, imagination and will are also unknown. But who can say what material substance is the carrier of radio waves which pass from the transmitting to the receiving antenna? In cybernetics no difficulties arise due to the fact that the information carrier is not known, for the communications engineer utilizes radio waves while knowing nothing of the nature of their carrier.

The definition of the concept "information" may now be clarified if we call information "a physical action which influences thought."

Therefore information has two sides: *semantics*, which is included in the *action* of given information on *thought*, and the information carrier--a physical phenomenon which exerts a semantic action on thought.

The Universality of Cybernetics

During the control of action we must keep in mind the entire aggregate of information concerning the environment, since even a certain insignificant, inexact circumstance may exert a serious influence on action effectiveness.

This means that during the development of models and in the application of cybernetic logic it is necessary to utilize knowledge relative ordinarily to various fields, including physics, chemistry, biology, psychology, mechanics, mathematics, literature, etc. In other words it is necessary "to take kindness wherever it lies."

Cybernetic methods of thought fit with difficulty into the categories of existing psychological theories. Therefore it is difficult to establish a sequential connection between results obtained in cybernetics and the author must be excused due to the fact that the statement of the material in the following chapter is not arranged according to a strictly rational plan.

Any reasoning, any direction, any creative idea may be employed in cybernetics if they are effective and notwithstanding how they are obtained. In this connection between the ideas which differ in nature and in origin, relationships which are established with the aim of such control of activity which could lead with success to an established purpose, as well as to the freedom of cybernetic thought to touch upon all problems of influence on surrounding nature and man in order to obtain effective information concerning these and for effective influences on these--all of this is included in the *universality of cybernetics.*

Recent Results

The universality of cybernetic thought appears in analogies which associate in the most unexpected manner points of the most diverse categories. We shall cite several typical examples.

Population reaction to psychological influence. At the beginning of the XXth Century, some neuropathologist, in particular the French investigator Lui Lamik and the Englishman Charles S. Sherrington revealed that during the stimulation of a nerve ending an electrical wave was propagated along the nerve which had the shape shown in Figure 1, where time is shown along the axis of the abscissa and difference in potential along the axis of the ordinate. Danny Gabor revealed that the wave, carrying an instantaneous pulse through an electrical filter, may be examined as the result of waves overlapping each other, similar in shape to the curve of Lapik and displaced in time with respect to each other. This shape is displayed by a wave which is propagated in a circuit consisting of nerves and nerve centers (ganglions), and is transmitted from one nerve to another through a formation called a synapse, without contact between nerves.

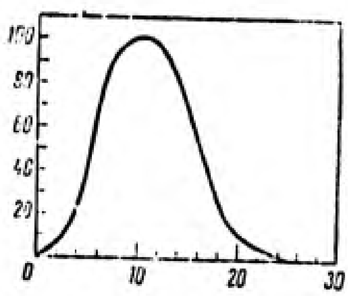

Figure 1.

During searches for other analogies it was established that an electronical lamp has a similarity with the synapse, since the connection between the electrodes of the lamp is also accomplished through a poorly conducting medium. Thus the nerve center and the electrical filter act according to the same principle, but are distinguished from each other by their structure.

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If we now consider that electrical pulses, propagated along the nerves, are almost always carriers of information and that pulses in an electrical circuit also often serve to transmit information, then in connection with this analogy we may assume that the reaction on the mechanism which utilizes information upon stimulation must be described by a curve similar in shape to the Lapik curve, even when the stimulation is not created by electrical pulses. In particular, such a mechanism may be employed to examine a population which receives oral or visual information.

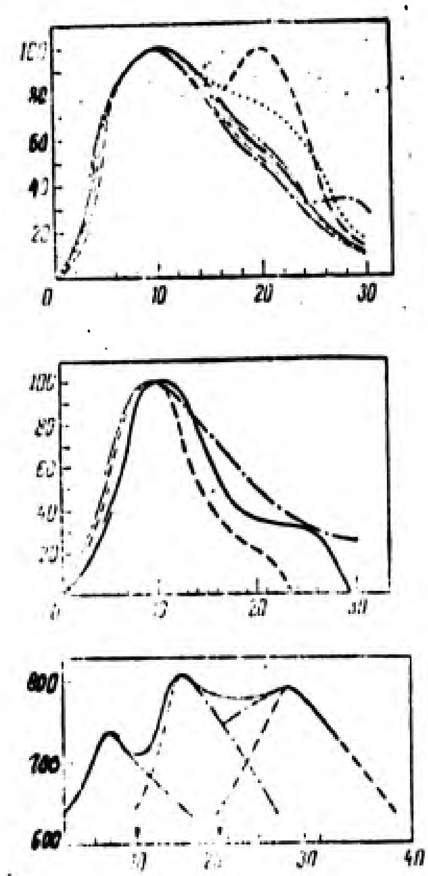


Figure 2. The Curves on the Upper Drawing Show the Course of a Clearance Sale of Identical Goods During One Month; the Middle Drawing Represents a Clearance Sale Which Was Held for One Week at Various Times of the Year; the Lower Graph Reveals the Course of a Clearance Sale During an Extended Period of Time; the Arrows Designate Days When Intensive Advertising of the Goods was Accomplished. If we compare all these curves, as has been done in Figure 3, then we see that they have the same shape.

The following experiment was accomplished in order to check the analogy method. The customers of a large Paris store were examined as a mechanism. Communications concerning an advertised clearance sale of goods served as information, and receipts during the sale were accepted as a reaction measurement. The goods advertised included stockings, gloves, perfumed articles, underwear and household goods. The advertised clearance sales were held at different times of the year and their duration was also varied. After statistical processing of the results, curves were obtained which are shown in the drawings. The peaks of these curves have an abscissa which equals 10 and the ordinate equals 100.

It is possible to conclude from this test that *a sufficiently uniform population reacts to psychological influence in a specific way which is characteristic for the population.*

For the discovery of this conformity with law we are indebted to the method of thinking by analogy, described above in all details.

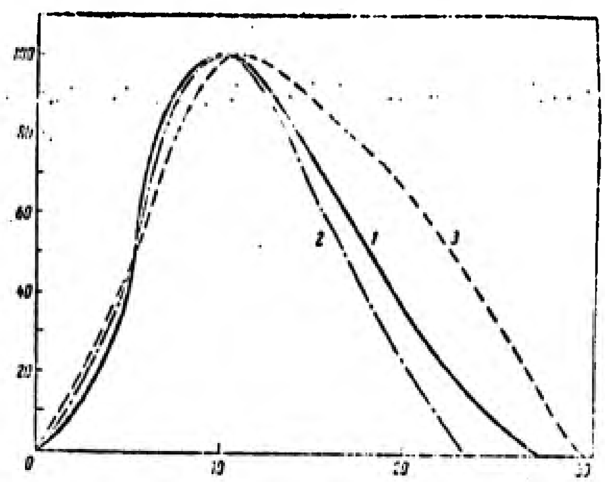


Figure 3. Both Infinitely Removed Phenomena as Well as Phenomena Approaching Complete Coincidence of Structure May be Easily Compared Where Their Functions are Identical. The processes of pulse transmission in the nervous system of a man are described by the same mathematical curve as the dependence of demand for goods on the course of an advertising campaign.

The work of an enterprise. If the method of analogies is applied in another field--with respect to the behavior of an individual organ of an animal organism, or of an individual living being, or of human society, we note that:

the actions of the individual organs of an animal are in agreement among themselves and their purpose, in all probability, is to support the existence of the animal and to give to it the capability to act, which is a need which the animal attempts to satisfy;

the actions of human organs and frequently their structure as well has much in common with the actions of animal organs and in their functioning follow the same purpose; but in almost every man the thinking function is developed to a considerably greater degree and the needs which a man attempts to satisfy have a special nature: these are *esthetic requirements*.

Therefore the obvious purpose of the activity of man consists of the satisfaction of his needs.

In prehistoric times people joined together for the hunt, while under contemporary conditions they join together in production groups so that due to the cooperative direction of their efforts they may satisfy their needs which they could not do if each one acted separately, or so that they may enjoy themselves together, when satisfaction cannot be obtained by each one of them individually.

An analysis of contemporary social relationships with the help of analogies between animal and man, between man and society, between the organs of man and the organs of society, isolates those features in the life of society which up to the present time have remained unnoticed or could not be investigated.

a) *The action of all of human society consists of the satisfaction of the needs of its members.* We shall call this function the *economic function* of society. A group of persons, the activity of which serves to fulfill an economic function of society shall be called an *enterprise*.

For example, a factory which produces pneumatic tires is an enterprise, the function of which consists of the production of tires in order to satisfy the needs of people who use motor vehicles.

A library is an enterprise, the function of which is reduced to placing books at the disposal of persons who experience reading needs.

An entire nation, the main function of which consists of providing all its citizens with well being and happiness, and for which they feel a need, also represents an enterprise.

b) The work of an enterprise is comprised of the actions of individual people who utilize the weapons of production: tools, machines, transportation facilities, etc. *An enterprise provides the production process with the weapons of production, while the workers of the enterprise are the source of information.*

The usually cited example of the worker who pours metal into a casting mold has the aim of showing that there are workers in the enterprises who are basically sources of physical energy. But since as a result of production training it is possible to obtain the same production with a lower expenditure of physical labor, it is clear that in the case of physical labor actions of the worker are controlled by information. Even the fact that certain people experience difficulty in coping with production training indicates that during his work the worker utilizes to the maximum his inherent capability for information processing.

When the worker controls the machine his complex motions which are accomplished without great physical efforts send to the machine information for the accomplishment of its individual parts of power operations. The worker in the given case does not expend his energy for the fulfillment of these operations.

The actions of all workers of the enterprise, beginning with the brigade leader and ending with the director, are reduced to the assignment, at the required moment, of information required for enterprise functioning.

c) The workers of an enterprise differ from each other according to the quantity and quality of information which they furnish. *The production qualification* of a worker is the aggregate of qualities which make up the information which he possesses in his profession, the force of imagination which he allots for development on the basis of this new information, and finally, his capability for transmitting information to other workers.

d) Keeping in mind that the activity of individual members of society is reduced mainly to the exchange of information, cybernetics rationally solves the *"public relations" problem.* This is what the Americans call the problem, which often arises during human relations and is connected with the fact that it is sometimes difficult for them to understand each other and to come to a common opinion. These difficulties arise in the relationships between managers and their associates, between the seller and the buyer, between the service worker and the administrative institution, etc.

Cybernetics examines "public relations" as *a special form of the transmission of information.* Similar to the transmission of information by radio, where the transmitter and the receiver must be tuned electrically to the same frequency so that the transmission may be accomplished without distortions, the thought images of the man who transmits information and the man who receives it also must be in agreement. And since the information receiver does not know what information he will be given the information transmitter must in an appropriate manner accommodate him and thus he must know:

what information the information receiver already possesses and in what form it was communicated to him;

to what extent the receiver is capable of mastering new information.

Based on this, the transmitter of new information must put it into a form which is accessible for receiver perception.

Briefly put, cybernetics sees a simple solution to the problem of "public relations" *in the assimilation of information transmission facilities.*

In particular, the circumstantial study of such information transfer facilities as speech, drawing, motion pictures, must become a part of popular education which will lead to good professional qualification.

e) Finally, in observing human reaction to psychological influence, it is possible to assume that the enterprise consists of *a self-organizing unit.*

Beginning with the worker, who has his specific method of communication with the machine, and ending with the director, who has his characteristic method of managing people, all production workers act within the limits of the tasks placed before them in agreement with characteristic initiative.

For example, in construction it is necessary to transfer workers from one brigade to another depending on urgency in the fulfillment of certain work. The organization of the work is modified, depending on circumstances and in accordance with indicators from the work producer. Therefore such a structure represents a self-organizing production unit.

The following aspects are isolated within the concept of the self-organizing production unit:

during the organization of the enterprise particular attention is paid to its action, rather than to its structure. The structure of an enterprise may be changed if required so that the enterprise may accomplish its function;

the activity of each production unit is determined by targets assigned to it;

the information which is exchanged by production unit managers pertains to an aim, or to the results of their activity, which amounts to the same thing.

Thus the fundamental essence of an enterprise consists of the fact that it is an association of people whose basic contribution within the enterprise is the furnishing of information. Therefore the industrial qualifications of the workers of the enterprise, as well as a professional training, have a great deal of significance for the correct functioning of an economic mechanism. The problem of "public relations" is solved by studying information transmission facilities. An investigation of the essence of an enterprise has revealed that it consists of self-organizing units. Numerous problems associated with the organization of an enterprise are solved, based on this position.

The cybernetics of machines. In order to construct an analogy in cybernetics N. Wiener always proceeded from the concept of "machine" or of "machine organs." At first, therefore, cybernetics was occupied with machines.

But what is a machine?

The most ancient machine known to us is a lathe (2000 B.C.). A wooden shaft, from which it was desired to turn a column, was suspended between two trees and was rotated by means of a rope. A man held the cutter and pressed it against the rotating shaft. He moved the cutter and placed it in the required position, while using a board in parallel to the shaft undergoing treatment.

The contemporary lathe has the same basic parts: two chucks, which hold the part undergoing processing and by means of a motor set it in motion; a cutter, which is held in a support, rather than in the workers' hands; the support is moved under the influence of other parts of the lathe.

A machine is created in order to *replace man in the fulfillment of a certain action.*

An organ accomplishing an action which causes a change in the environment encompassing the purpose, is called an *effector*. The remaining organs, which are intended for control of effector action are *cybernetic organs*.

From the methodological point of view *the control of a machine is an intellectual operation and cybernetic organs replace man in the fulfillment of such operations*.

Here we must make one remark which is very rarely formulated with sufficient accuracy. Effectively operating machines are not those machines which repeat the gestures and logical operations of a man, i.e., *of work*. Those machines are considered to be effective which, at a given moment, utilize the simplest means for the solution of a given production problem (and these are already employed in production). A problem is before us which requires a solution and they solve it with satisfactory means, from a mechanical point of view. These machines are *simulators*.

Here is one example.

At the end of the First World War the first hydroelectric station was built in the Rocky Mountains which was controlled from a distance. A robot in the form of a man with legs, a trunk and a head was equipped with telephone apparatus, and was placed on rails in front of the instruments and control buttons. By raising his "arm" to the instrument scales he considered their indications, by which the condition of the station was determined (level of the water, voltage, power, etc.), and transmitted these indications several hundred kilometers into a valley. From the valley came answers, containing instructions concerning maneuvers which the robot had to accomplish. Then the robot moved along the rails and pressed the appropriate control buttons. Information was transmitted in the form of five notes of a musical scale.

At the present devices for remote readings and remote commands are situated in a fixed housing, while electrical pulses, which pass through distributing devices to the appropriate performing elements, serve as information carriers. In external shape, the performing elements no longer resemble a man and although they carry out logical operations in place of a man they accomplish these through different technical methods. These are simulators.

Machine elements or machines which control themselves are called *automatons*. Automatism is attained by means of cybernetic elements. Therefore many engineers confuse automation with cybernetics and even with the mathematical theory of machine-automatons.

But for the engineer *a mathematical theory is a model* of phenomena which exist in nature, the advantage of which consists of the fact that this model changes in agreement with strictly defined rules--the rules of logic. The definiteness of these rules facilitates their application, especially with the help of computers, or of "thinking" machines. The application of mathematical models is a particular case of cybernetic logic, when deductive argument is wedged in between two arguments on analogy. Only in the case when conclusions obtained as a result of the mathematical transformations of a model are confirmed by experiment does theory find a practical application. In other words, *cybernetic logic does not separate technology and theory.*

For example, if we investigate work on the development of artificial satellites in different countries, we note that shortcomings are always caused by technical reasons, rather than by shortcomings in theory.

Recent examples. The originality of cybernetical logic and its contrast to the deductive method of thinking was clearly emphasized in recent methodological works.

First we must note the meaningful work of the Polish Professor Kh. Gren'yevskiy, "Cybernetics without Mathematics" (Warsaw, 1958), in which he systematically studies the question of the presentation of natural phenomena in the form of models. These are models which are called *"dialectical models"*, i.e., in which analogies with the original are established by means of its description. The language of the models of Gren'yevskiy is not mathematical, but is a special graphic language which is quite similar to the diagrams of electronic machines.

But the very diversity itself of phenomena studied by this method indicates the great possibilities of the modeling method, i.e., of the method of cybernetic logic. In particular such simple models easily permit us to understand what behavior according to Pavlov consists of, and they also indicate avenues for the development of machines to translate from one language to another.

The *feedback mechanism*, which ordinarily interests the engineer only in the case when it is stable (negative feedback), and which may be described mathematically only when it is linear, was applied by the English scholar Stanley Johnson in biology in its most general form with the use of ordinary language. Henri Labori (France) also describes this mechanism, using a diagram of his countryman Pierre de Latil, which was similar to the models of Professor Gren'yevskiy.

The basic ideas of the mathematical information theory of Shannon, who compared it with the kinetic theory of gases, was investigated by the French investigator Francois Bonsak, who succeeded in revealing the nature of the paradoxes of statistical thermodynamics and in eliminating these, as well as in interpreting Shannon's mathematical results in the fields of biology and psychology.

The study of economics with the aid of cybernetic logic is being carried out in the Institute of Applied Economic Sciences in Paris under the leadership of Professor Francois Perru. Thus the development of the cybernetic concepts expands the field of cybernetics, which has been limited initially by the mathematical theory of machine-automatons and by the application of this theory to certain mechanisms, and permits us to examine cybernetics as an original method of thinking; the form which has been most studied is the method of analogies and the utilization of models.

The results already obtained along this avenue permit us to state that such a concept of cybernetics will become general in the future.

WHERE PREDICTION AND FORESIGHT ARE NEEDED

CYBERNETIC AND ECONOMIC CONTROL

Academician V. Glushkov

The period of intensive development of cybernetics began at the moment of the appearance of the first high-speed electronic computers, as a result of which it became possible to solve serious problems of automation on a fundamentally new level--in the sphere of the intellectual activity of man. Under contemporary conditions, of course, it is not always easy to separate physical labor from intellectual labor. However fields of human activity exist which have always been accepted as belonging to the sphere of intellectual labor alone. Our concern is specifically with these fields.

Naturally first of all two questions arise: In what measure is the application of automated facilities possible in intellectual work, and if they are possible, is there a requirement for them?

It is already possible now to give a fully definitive answer to the first of these questions: no limits exist in the application of automated devices in the intellectual activity of man. Moreover, even current so-called universal electronic digital machines are suitable in principle--although far from being well-adapted--for the automation of intellectual activity of any type. We stop only to study and to describe exactly the controlling regularities of this activity. It is true that today these regularities have been studied only in rather simple cases. However the study of the regularities of thinking processes under complex conditions (for example, within the sphere of creative activity) has only begun and doubtless will require the expenditure of tremendous effort by collectives of highly-qualified scholars.

In answering the second question, we may isolate a number of fields of human intellectual activity where even today automation is urgently required and may noticeably accelerate the rates of our forward progress.

The first and at the present time the most important of these is a system for the calculation, planning and control of the economy. It is known that the quantity of information which is processed by this system increases much more rapidly than production increases. In addition, the race of mechanization and automation (and therefore, the increase in productive labor as well) in the sphere of planning, control and calculation were, up until recent times, considerably less than in the sphere of material production.

As a result the productivity of labor of a large collective of engineer-technical and office workers, as well as economists, which are occupied in the planning, control and calculation sphere, increases extremely slowly. This has a negative effect on the development of the entire national economy, causes serious defects and miscalculations in planning, and does not permit the utilization to the full of the advantages of the socialistic structure.

The volume of information arising from production, and therefore production difficulties as well will increase in proportion to a further increase in production. Tentative calculations reveal that if the existing level of the quality of planning is maintained (and this level still does not correspond to the requirements of the present day) and if the level of the technical base remains unchanged in the sphere of planning, control and calculation, by the year 1980 the entire adult population of the Soviet Union will be required to serve in this sphere.

Therefore the automation of calculation, planning and control of the economy is a problem of tremendous, overall state importance. To a significant degree part of the problem may be solved on the basis of universal electronic digital machines which already exist.

But the matter cannot be reduced only to the development and manufacture of a required quantity of electronic computers. In this concept the given problem would be relatively simple, while its solution would not lead to the expected economic effect.

A basic task in the introduction of electronic computer technology into the sphere of calculation, planning and control of the economy consists not in the simple replacement of manual labor with a different type of calculations, but in a basic change of the methods themselves of administrative work, and in the transition to optimum planning and control.

The essence of optimum planning and control consists of selecting at a given moment the best variant which would provide a solution for these problems in the shortest possible historical periods from the countless numbers of variants of the development of our national economy in the direction of the solution of general problems raised by the Party. The transition to optimum planning and control means the elimination of those numerous miscalculations which are still tolerated by our planning and operating bodies. It means the fullest use of all the reserves of our economics, which results from the tremendous advantages which the socialistic method of production gives us.

Now it is still difficult to give the exact figure, but it would hardly be an exaggeration to consider that the full transition to optimum methods of planning and control will at least permit us to double the rate of growth of our economy and the rate of growth in the well being of the S viet people.

Of course a great deal of work will be required in order to solve the problems of the automation of economic calculation, planning and control on the basis of electronic computer technology.

The fact is that the broad introduction of cybernetic methods in economic control is characterized by many distinguishing features in comparison with the use of electronic computer technology for scientific and engineering-technical calculations. The first of these is the fact that information flows which are subject to processing significantly exceed the volumes of information required for the solution of scientific-technical problems. In order to guarantee the solution of economic problems, electronic computers of average output (of the order of 50,000 operations per second) must process such a quantity of input information, which if transferred to punched cards would yield a figure of the order of 10 billion pieces per month. It is completely clear that the use of punched cards alone for this purpose is practically impossible, but for information input and output they represent specific requirements.

An initial and specifically required condition for the full automation of economic information processing is the automation of the primary selection of basic data.

The concept of operations carried out by electronic computers has essentially broadened. In the accomplishment of some type of engineering calculation or in the solution of some other scientific problems, the machine mainly carries out arithmetic operations, including addition, subtraction and multiplication and division, while in connection with the processing of economic information a large part of the operation consists of operations of sorting, the formation of large blocks, etc. The requirement for their accomplishment on an ever-increasing scale presents new, additional demands for high-speed operation of electronic digital machines.

Higher requirements are established in programming, for in a program of average complexity utilized in the processing of economic information, there are a significantly greater number of instructions than in a similar program for scientific or engineering calculations. In addition, the problem of the correct organization of the work of programers, and of the rational distribution of work among them, is essentially a complex one.

In fact, these are typical problems which arise in the study of complex systems and their solution is studied by a new science--the theory of large systems.

Much depends on the correct approach to the introduction of computer technology for economic control. In this problem it is necessary to utilize the systemic approach, i.e., not to introduce individual machines (even if they are very good and are suitable for the solution of planning-economic problems), but to introduce control systems. This means that the development of a system of algorithms, of the means of the primary collection of information and communications methods together with the construction of appropriate electronic computers must be accomplished simultaneously by the same collective of developers. It is obvious that the accomplishment of these tasks must be preceded by laborious work at the places of introduction (in enterprises and in organizations) in the investigation of operations, in the preparation of appropriate instructions for the accomplishment of the entire complex of technical-organizational measures which provide for the introduction of an automated control system.

In view of the complexity of automated control systems and shortcomings in the corresponding cadres for their technical servicing, it is necessary to provide for correct order in their production and in the organization of their use.

It is completely understandable that the production of such systems must be complex: in addition to technical equipment for the processing of information (EVM) [electronic computer] it is necessary to produce also devices for the assembly and transmission of information (sensors, communication devices, etc.), as well as for the transmission of an entire complex of input and output information.

We may only conceive of the installation, alignment, organization of use and repair of these systems as centralized. It is obviously necessary to provide for a system of guarantees of uninterrupted work, for a sequence of operational transmission of functions (during a breakdown) to other systems or to computer centers, etc., etc. This does not exclude, but rather intensifies, the need to create advanced bases or research groups at enterprises where typical control systems are introduced;

these groups would study the improvement of system functioning, the development of algorithms and programs lacking in the initial search, and the preparation of additional technical requirements. All of the problems enumerated must be considered in the development of a single state automatic system for the processing of planning-economic information and for economic control, which unites the activity of all lower-echelon automated control systems, functioning at individual enterprises or in groups of smaller computer centers for the processing of planning-economic information. We must keep in mind the circumstance that the requirements above must be considered during the manufacture and introduction of control systems, beginning at the lowest level (at enterprises), while foreseeing the possibility in the informational plan of joining these systems with the aid of modern communication lines to territorial information processing centers and also foreseeing the transmission of data required to all higher control elements.

The effect which may be achieved by the system described is tremendous. The solution of a number of particular planning-economic problems, included in existing computer centers, reveals that even at the present time not less than 10% of facilities and material resources expended in the development of production is lost due to lack of optimum planning.

Specialists in the field of cybernetics are already accustomed, for example, to the fact that in a transition to automatic transportation planning, savings amounting to 10-15%, and in certain cases up to 50-60%, are obtained as a rule. Thus a complex of problems accomplished by the Institute of Cybernetics of the Academy of Sciences of the Ukranian SSR, in conjunction with Gosavtodor NII [State Motor Vehicle Road Scientific Research Institute] of the Ministry of Motor Vehicle Transport and Highways of the Ukranian SSR, on the operational planning of motor vehicle transport work in cities of the Ukranian SSR (Kiev, Odessa, L'vov, Khar'kov, Dnepropetrovsk, Krivoy Rog, Cherkassy, Simferopol', etc.) permitted a yearly saving of more than 1 billion rubles.

In recent times the Institute of Cybernetics of the Academy of Sciences of the Ukranian SSR has solved and introduced into planning and control practice more than 300 various undertakings, which guarantees savings of government facilities of many millions of rubles. A study of the significant economic effect resulting from these solutions emphasizes with great clearness that current rates and scales for the introduction of computer technology into economic control cannot satisfy us, and that they still lag behind the fast-growing questions of our national economy.

A very important segment of intellectual work which is extremely required in automation is engineer-construction work and technical design.

The problems which occasionally arise here are so complex that in a number of cases even now there is no human collective which is in a position within a reasonable length of time to find, in fact, the best designed version. We shall take as an example the problem of finding the best plan for a railroad several hundred kilometers in length, which passes through a mountainous area. An investigation conducted in the Institute of Cybernetics of the Academy of Sciences of the Ukranian SSR revealed that with the usual (manual) method of planning only one of the parts of this problem (the optimal design) would not be solved with the required degree of accuracy in less than 50 years! A computer expends a total of several hours in the solution of this problem.

At the present time the work of designers in the best case is automated only in those parts which touch upon the fulfillment of the most complex calculations. The transition to optimal design will require complex automation, when all stages of design, including evaluation and comparison of various versions will be fulfilled automatically by machines. Such a transition will demand important changes in the direction of scientific investigations. Previously the basic efforts of specialists were directed toward the development of design methods calculated for use by man, whereas now the center of gravity must shift toward the development of such methods which will be oriented toward use by electronic calculators. In this connection it will be necessary to maintain entire libraries of standard programs suitable for any specific planned tasks, rather than partial programs, compiled anew for each newly developed design.

Several works on the automation of technical design processes have been accomplished in the Institute of Cybernetics of the Academy of Sciences of the Ukranian SSR. In addition to the optimal railroad profiling already mentioned, we may, as an example, indicate still another complex automation of design processes and of the manufacture of ship hull parts and to the design of electrical, gas and water distribution networks. The experiments of our Institute and of other Institutes has permitted us to hope that the effect of the ubiquitous transition to design automation might save many billions of rubles per year.

Of course the solution of this problem will require a great deal of time and will encompass separate stages.

An important area of human intellectual activity, where a known requirement for automation is also felt, is that of scientific creativity. An increase in scale has now been achieved, just as in technical design, first of all as the result of an increase in the number of scientific workers and auxiliary personnel. The rates of this growth are such that if this condition is maintained in the future, in 150-200 years the entire population of the world would have to be transformed into workers of scientific-research institutes.

This indicates convincingly the necessity of applying automation methods in the development of science itself. The question of the complex automation of this process at the present time has been in preparation to a much lesser degree than automation of the processes of economic planning and technical design. Nevertheless, definite prospects have also been noted here.

Aside from the already known automation of various types of calculations and computations accomplished during the process of scientific creativity, the question is now being solved of the automation of inquiry-informational and reference work, which occupies a large amount of time in the work of the contemporary scholar. Tempting prospects are uncovered in the automation (on the basis of universal electronic digital machines) of experiments and observations with the simultaneous processing of data obtained, first of all, in contemporary experimental atomic physics, stellar astronomy, hydromechanics, aeromechanics and in a number of other sciences.

However maximum interest is presented, apparently, by the automation of proofs of theorems within the framework of various deductive theories and by the construction of theoretical diagrams which generalize the results of experiments. Here we have obtained only the first limited results, however the prospects revealed by these are indeed magnificent. The fact is that the capacity of the brain of a man establishes a known limit for the complexity of theories and proofs created by him. Cases are already encountered now in which an investigator wastes 10 years of tense intellectual labor in the solution of a certain problem in mathematics or theoretical physics.

The attraction of machines, even for the partial automation of similar labor, is that is permits us to sharply curtail the periods of time required for the solution of complex creative problems, and increases tremendously the intellectual power of humanity. Perhaps a much more important result of this automation will be not simply the decrease in periods of time involved and an increase in the degree of regularity of scientific research, but the capability of constructing theories of such complexity that they are practically inaccessible to man. Of course the final aim of the construction of such theories involves the possibility of obtaining practical conclusions from them which multiply the power of man over nature.

From all that has been said it is clear that the development of cybernetics and the continuous improvement of its technical base to a significant degree determine further successes in our science, technology and national economy. Just as the total output of electrical stations and other powerful installations determines the power might of a nation, the total output of electronic digital machines and other cybernetic devices determines its informational-intellectual might. In proportion to production complexity and other successes of science and technology, the informational-intellectual power will, to an even greater extent, define the industrial-economic potential of a state, for only a sufficient level of informational armament makes possible the rational utilization of productive and human resources. Achieved on the basis of cybernetics and electronic computer technology, the acceleration in the rates of growth of science has tremendous significance and may become the decisive factor in the economic competition between two systems.

All the possibilities exist in our country for the solution of the problems enumerated in the shortest periods. The approaching Communist society must have and certainly will have the most effective system, automated to the maximum extent, for control of its economy, the most improved forms of production automation, and it will also widely employ cybernetic means in the intellectual activity of man.

CYBERNETICS AND THE MODELING OF SOCIAL PROCESSES

Candidate of Philosophical Sciences E. Arab-Ogly

Cybernetics is a science which in many respects is paradoxical; it places scholars in a dead-end almost as often as it extricates them from a whole series of dead-ends in our consciousness of the surrounding world. Paradoxes have accompanied cybernetics even from its birth and during the first days of its existence as an independent science. In fact, cybernetics had hardly appeared in the world when it turned out that a book published more than 100 years ago contained not only the name invented for the new branch of knowledge, but also defined its place in the system of sciences and gave a description of the object of the investigation.

This definition, which belongs to the outstanding French mathematician Andre Marie Ampere, deserves that we reproduce it here in full, "*Cybernetics*. The relationships of people to people, studied by two preceding sciences; this is only a small part of the objects which government must take care of; its attention is also continuously demanded by the maintenance of the social order, the execution of laws, the just distribution of taxes, the choice of people which it must appoint to responsibility, and everything which promotes improvement in the social states. It must constantly choose between various measures, the most suitable for the achievement of its purpose; and only due to intensive study and comparison of various elements, granted to it for this selection by the knowledge of everything that pertains to a nation, it is capable to govern in agreement with its character, customs, means of existence and prosperity of organization and with laws which may serve the common rules of behavior and with which it governs in every common case. For, only after all sciences, which occupy themselves with these various objects, it is necessary to place this, which the matter now concerns and which I call *cybernetics*, from the word χυβερνητιχη; this word, accepted at first in the narrow sense to designate the art of ship navigation, has obtained usage among the Greeks themselves in the incomparably broader sense of *the art of control in general.*"

After the origin of cybernetics the reference itself by Ampere to this term, and moreover the definition given by him was accepted by many as simply another curiosity in the history of science. Having begun its triumphal march, cybernetics, as it seemed then, was whatever was convenient--a branch of mathematics, a theory of automatic devices, applied science in the design of electronic computers, the technology of electronic modeling, etc., but never a social science, never a political discipline, as considered by Ampere in his time, who had placed it in his classification of sciences between diplomacy and the theory of power. Moreover, the first attempts by cybernetics to invade the field of sociology--just as pretentious as they were superficial--in general forced doubts about the prospects of its fruitful application in social sciences. The expression "social cybernetics" with a well-known basis long ago became a nominal expression for the designation of idealogical speculations, which were accompanied by the outstanding successes of this science in the field of natural science and technology, and frightened the sociologists from cybernetics, and the cyberneticists from the sociologists. Only a few serious scholars were convinced that in science concerning society cybernetics had a future no less important than that of natural science and technology. Among these was also the founder of this new branch of knowledge Norbert Wiener, who in his autobiography subsequently wrote: "It became clear to me almost from the very beginning that new concepts concerning information and control would involve a new interpretation of man, of human knowledge concerning the world and society."

The Cybernetic Invasion of the Social Sciences

The penetration of cybernetics into both natural science and sociology was accompanied by a sharp idealogical struggle, comparable perhaps in its social response to the assertion of the heliocentric system, to Darwinism and the theory of relativity. This was completely understandable, for, just as they had in their own time, cybernetics not only overturned many prejudices in science and habitual concepts in ordinary consciousness, but also encroached upon social interests invested in these. This polemic has not ceased by far, and cybernetics continues to be an object of sharp attack. Nevertheless the times when it was necessary to defend the right of cybernetics to existence have disappeared into the past.

Although the penetration of cybernetic achievements, the techniques and methodology of investigation created by it, as well as its terms and categories began later in the social sciences and progressed more slowly than in the natural sciences, up to the present time it has convincingly demonstrated its fruitfulness and prospects. Electronic computers, developed through cybernetics, have already found a wide application in social sciences as technical facilities for the collection and processing of statistical data and other information concerning various aspects of social life. Immediately thereafter the modeling of individual social processes on electronic machines began to lay a foundation for itself in political economy, demography, specific sociology, psychology and pedagogy. This in turn unavoidably led to conflict between many phenomena and regularities in society with cybernetic concepts, to instructive analogies from the point of view of form among processes occurring in society and the functioning of any other highly-organized, self-regulating system. Finally this led logically to the concept of the possibility of employing certain general concepts of cybernetics for the improvement of the organization and control of society, including economic planning and prediction, legislation, teaching processes, etc.

Now Ampere's definition of cybernetics does not appear quite as absurd as it seemed previously. Of course it would occur to no one today to reduce cybernetics to the scientific control of society, or to organize the scientific control of society with cybernetics. However, it becomes increasingly clear that cybernetics will not be fully valid if its successes are not applied in the science of society while the scientific control of society will suffer serious damage in the case of refusal to utilize the achievements of cybernetics. The more we think about it the harder it is to imagine in what manner, if do not turn to cybernetics, we will be able to manage all of the information required for control, define optimum solutions for economic problems, strike a balance in the national economy, foresee social processes and the consequences of legislation.

It should be noted that cybernetics by far does not intend to replace any of the specialized sciences; also it does not pretend to be a science which stands above other sciences, i.e., the next higher "science of sciences." Its "universality" is of a different type and in certain aspects reminds one of mathematics, although it is not so general, since it is limited by a formal resemblence to the functioning of self-regulating, "automatic" systems. As long as such systems exist in reality in the unlimited and limited world, in society and in technology created by man, so will cybernetics not be considered a natural, a social, or a technical science parexellence (for the most part). Moreover it is perhaps the first breach in the wall which specialization of scientific knowledge of the world has erected between natural science and sociology, and by the same token may represent the embodiment of the profound prediction of Marx, made in his economic-philosophical writings of 1844: "Subsequently natural science will include the science of man in the same measure as the science of man includes natural science: this will be one science."

The application of cybernetics in social sciences, therefore, has nothing in common with attempts to extend to society the laws of physics or biology, which has repeatedly been attempted in the past and which, of course, was rebuffed by the Marxists. The concepts, categories and laws of cybernetics (regardless of their origin!) do not belong exclusively either to natural science or to sociology; their use, therefore, is fully legitimate in either area, just as in technology. With their help it may not only be possible to accomplish a description of social processes and phenomena in the language of cybernetics, i.e., to systematize knowledge already accumulated concerning society from a specific point of view, and also to obtain new knowledge concerning society if in this connection the peculiarities and characteristics of the effects of information, control and feedback in social systems are considered.

The application of cybernetics in social sciences coincided with the process of their "mathematization"-- in other words, with the beginning of the broad use in these sciences of quantitative analysis, and mathematical methods of investigation in general: game theory, theory of graphs, operational analysis, etc. This was a coincidence not only in time, but first of all in content of the process itself. Cybernetics proved to be the main channel for the introduction of mathematics into social sciences because, on the one hand, it permitted to a great extent the formalization of our knowledge concerning society and made it accessible for translation into the language of mathematics; on the other hand, by leading to the development of high-speed computers, it granted the technical capability for the accomplishment of complex mathematical operations. Moreover new and tempting prospects for the development of social sciences were revealed, with respect to which the well-known remark of Marx maintains its force, to the effect that science, in general, only becomes mature when it masters mathematics. It is true that for the present the application of cybernetics, as well as mathematical methods of investigation, in social sciences still remains in the initial stage. This is explained mainly by the incomparably greater complexity of social phenomena and processes than those which are dealt with in physics or even in biology. It is said that Albert Einstein was once asked why it happened that while human intellect penetrates so deeply into the structure of the atom, we remain incapable of developing the political means to prevent our death from the atom. "This is because politics is more difficult that physics!" answered the great scholar.

However, in conjunction with similar objective difficulties, subjective causes also exist which interfere with the application of cybernetics and mathematics in social sciences. Certainly the main point is the broadly held delusion that the use of mathematical methods by their very nature are reduced to operations with quantity and are not suitable for the study of qualitative characteristics of a phenomena. From this it is concluded that as in the life of society the qualitative characteristic of phenomena in processes clearly predominates over their quantitative community, this means that the application of mathematics in social sciences unavoidably will remain much more limited when compared with natural science. However, we must emphasize that these errors, no matter how convincing they appear at first glance, in principle, represent complete confusion.

First of all mathematical methods of investigation are certainly not exhausted by quantitative analysis, while quantitative analysis in its own turn is not identical to the analysis of quantity. The fact, already established by the dialectical method of thought, that gradual quantitative changes lead to fundamental, qualitative abrupt changes presupposes the fundamental possibility of quantitative expressions of any qualitative property of a given phenomena *studied by us* ("...*removed quality* equals *quantity*", wrote Marx). Mathematics itself includes both the quantitative analysis of quality relationships as well as the qualitative analysis of quantitative relationships.

This is why it would be naive to assume that calculation is the single benefit which the social sciences may extract from the application of electronic computers. Strictly speaking, as one specialist remarked wittily, we call the cybernetic devices "computers" only because the practical use which we have found for them almost disappeared for a long period of time. However, as is known, the same machines with appropriate programming may be quite successfully employed in the solution of a whole series of other problems, which surely presuppose operations associated with the qualitative evaluation of elements. These include the finding of a winning plan in so-called strategic games, particularly in chess; the solution of complex logical problems, which foresee the formulation of hypotheses and their checking; translation from one language to another and the decoding of writing systems; the modeling of various processes in nature and in society. One circumstance which deserves attention is that of the possibility, in the types of operations listed, that cybernetic devices may far surpass the capabilities of their designers and programmers and may find solutions which were not previously given to them and sometimes which are not even suspected; these devices may be designed and programmed in such a way that they possess a capability for self improvement during the process of their activity.

It must be said that in principle, from the point of view of theory, no social problems exist, the solution to which cannot be found with the aid of electronic computers *under the conditions that:* 1) Such a solution really exists; 2) The problem itself is formalized, i.e., it is written in comprehensive form and the machine is informed of the rules for its solution; 3) The machine is given all the information required for the solution of a given problem.

Frequently, in objecting to the formalization of social sciences and in derogating the value of the use in these sciences of the achievements of cybernetics, some persons maintain that the knowledge obtained by this method is entirely formal. This, of course, is not true; as shown by the history of natural science, scientific knowledge may be completely meaningful even if it is acquired with the aid of formal means. But the essence of the dispute between the adherents and the opponents of the application of cybernetics in social sciences is not involved in this point. Let us assume in fact that with the aid of mathematical methods of investigation, of electronic computers, and modeling as well, we find only a formal solution to specific social problems! In this case is it out of place to ask what knowledge or what supernatural means we may count on if we reject mathematics and cybernetics? The conditions required for the solution of social problems on electronic computers represent, in essence, ordinary requirements proposed for any serious scientific investigation.

The application of cybernetics also involves two other important consequences for the social sciences, taken as a whole.

One of these consists of the fact that the modeling of social phenomena and processes with time will permit us to resort on a large scale to experiment, although not on real processes in society (which is extremely complex and unjustified, for a number of reasons), but rather on their models. The first encouraging attempts at this type of experimentation on electronic modeling devices (analogs) were undertaken by Arnold Tastin, Otto J. M. Smith, et al. During recent years even more interesting investigations have been started in this direction in modeling with electronic computers. One case concerns the modeling of the behavior of voters in the presidential elections in the U.S.A., which was accomplished by a group of sociologists from Columbia University and was utilized in practice during the course of the election campaign of 1960; another case involves the modeling of demographic processes, when the Bureau of the Census made a satisfactory prognosis of the population increase in the country on the basis of the most probable behavior of several thousand American families. Now, since the principles of similar modeling on computers have been developed, we may expect their further wide use.

Another consequence which must be kept in mind is the forthcoming change in the relationship between so-called "general and specific" investigations in many social sciences. The fact is that the characteristic of a specific type of investigations in science as "specific" is not only purely arbitrary, but is more a derivative of their designation. A "specific" investigation in contrast to a "general" investigation represents for the most part the result of a direct generalization of a specific data on the basis of more or less full induction. The application of electronic computers has so expanded the empirical base of the social sciences and has increased the possibility of induction in these, that many investigations characterized as "specific" may be raised to the level of theoretical generalization of concrete material, which in the past was the privilege of "general" investigations.

An Electronic Analog of the Capitalistic System

In general, two methods exist for the construction of a physical model of any social process or phenomenon. *One method* is the construction of an appropriate system which in all respects will be similar to the social process which it describes. An example of such a model would be the modeling of money circulation by means of a closed electrical circuit, where the circulation of an electrical current would simulate the movement of money masses, batteries would fulfill the role of banks, delays in circulation due to various causes would be reproduced by switching in additional resistance and with capacitors, the mutual influence of parallel factors would be simulated with an inductive current, while the change in the cost of money could be simulated by a change in voltage, etc.

However this method is suitable only for the modeling of comparatively elementary social phenomena and relationships. In most cases social processes are so complex that the direct reproduction of these in the form of physical models goes beyond the limits of practical feasibility. Then it is expedient to resort to *another method*, namely, to describe a given social process mathematically, while simplifying the problem insofar as possible and then submitting it in sequence to transformation which will permit a comparatively simple design for an appropriate electronic analog. Although in this connection the model may be faultless from the mathematical point of view, in such an indirect model it is very difficult at first glance to detect the characteristic features of the initial process.

In investigating social processes, we turn most often to the second method of physical modeling. The remarkable possibilities inherent in the method of modeling social processes by means of electronic analogs may be judged on the basis of investigations which were accomplished in 1951-1953 at the University of California under the leadership of Professor Otto Smith. The interrelationship of available industrial equipment with the requirement for its amortization, the dependence of capital investments on national income and the desire for maximum profit, as well as delay in equipment delivery with respect to capital investments and the realization of consumer goods with respect to paid salaries--all of this was preliminarily worked out mathematically. The equations formulated, after certain simplifications, were represented graphically and then an appropriate electronic analog was constructed for the given (capitalistic) economic system.

The development of this type of analog does not present any kind of technical difficulties as soon as the design is worked out. Thus in O. Smith's analog capital movement was reproduced by an electrical current of specific frequency, delay in the manufacture of goods was represented by a transformer and for a time scale one year was equated to 200 micro-seconds, etc. The difficulty consists first of all in the definition of an objective criterion for those concepts and categories which are modeled; for example, "system stability", its "regulation", etc. It is here that the value of theoretical thought appears, which the machinery places weakly.

Such an electronic analog was utilized in order to analyze the stability of the economic system investigated and its reactions to various disturbances. First of all it was established in this connection that an economic system of this type is extremely unstable and *is subject to periodic fluctuations* approximately *once every 10 years*. Introduction into the system of the additional factor of ethical equipment wear, i.e., the tendency toward increasing the length of service of the equipment during a slow-down period and toward its renewal during an ascending period, which would be expected, only contributed to system instability and to an increase in the amplitude of fluctuations in production. "Speaking philosophically," writes Otto Smith, "two factors exist which influence system instability. One of these is information losses associated with time delay. This means that a capital depositor does not know about the affairs of other capital depositors until their articles of production appear in the market...The other factor is the positive feedback loop of demand. While the consumers increase their expenditures in proportion to the national income (instead of saving), a process of accumulation occurs which causes amplitude fluctuations to reach destructive proportions."

Thus the electronic model of the capitalistic system clearly demonstrated the cyclic nature of the development of capitalism and clearly revealed the inevitability and periodicity of economic crisis of overproduction and detected their reason: commodity production in the market, which leads to *production anarchy*, and the lagging of solvent demand behind capital accumulation, caused by *the private form of appropriation.*

Continuing his experiment with the electronic model of the capitalistic system, O. Smith found that the flow of capital investments, cheap credit and unfavorable prospects in the market contribute to a certain reduction in the frequency of fluctuation or to an increase in the duration of the economic cycle, but simultaneously the instability of the entire system increases; accelerated capital turnover leads to the same result. Further experiments forced O. Smith to the conclusion that there is practically no method of stabilizing a similar system and that all government efforts to regulate production are clearly unsound. "No matter what methods of regulation are employed--legislative measures, government tax policy, limitation of investitures, subsidies or government contracts, etc.--the stockholder is conversant with all this and takes appropriate action to obtain maximum profit," concludes Smith. "This is negative feedback, which almost completely eliminates the effectiveness of proposed methods of regulation."

Also characteristic of such an economic system is the extended preservation of the consequences introduced by various additional disturbances, for example, by wars. "In other words," Smith notes, "the disturbance introduced by the First World War in essence has still not faded...Events which led up to the Second World War were a reaction of the economic system to the previous disturbances; however the beginning of the War was a nonlinear process, which added energy to the system, i.e., by introducing a new disturbance."

The investigations of Professor Smith correspond to the course of the capitalistic method of production. *In addition they represent outstanding experimental confirmation of Marxist political economy, in particular, the theory of economic crises.* The achievements of applied cybernetics in sociology by the same token permit us to embody in electronic machines the purpose of Marx, which he wrote about in his letter to Engels: "I have repeatedly attempted--in order to analyze crises--to calculate these ascendings and descendings in the form of curves and thought (and I still think that with sufficiently reliable material it is possible) to derive mathematically from this the principal laws of crises."[1]

[1] K. Marx and F. Engels. Letter about "Capital", Moscow, 1948, p. 192.

This simplified model of the capitalistic method of production was set forth by me for the first time ten years ago (see "Problems of Philosophy", 1958, No. 5). Since that time it has repeatedly appeared in scientific and popular literature both in our country and abroad. However the commentaries which accompanied it may give rise to annoying confusion. The fact is that in the analog with which Professor Smith experimented, the movement of information concerning the state of the market was identified with the commodity mass itself, which under conditions of classical capitalistic economy was its material carrier. In addition during the past decade, after the Second World War, supplementary sources of information appeared concerning the state of the market which permitted predicting the course of economic processes independently of commodity mass movement and long before price changes could be detected. The paradox consists of the fact that similar foresight and prediction of market conjuncture became possible to a significant extent specifically due to the successes of economic modeling, in which Otto Smith himself was a pioneer, but by the same token one of the main conditions which he established as a basis for his model was objectively refuted (I came to the same conclusion later, of course).

As soon as the movement of information concerning the market condition is divorced from commodity mass movement and leads it, the course of the capitalistic cycle of reproduction changes sharply, and therefore other models with different parameters are required.

The duration of the capitalistic reproduction cycle is the sum of the duration of periods of increase, decline, depression and reviving, taken separately. The length of each period in the XIXth Century was longer than now and in general they possess a certain specific length. Why? Some reasons are completely obvious: in order to accomplish, let us say, investitures not in monies, but in machines and equipment, i.e., for the renewal of basic capital a certain amount of time is required so that these machines can be made. The intention of the capitalist to increase production cannot be accomplished instantaneously. The length of this period, therefore, to a well-known degree depends on the level of industrial development, on its capability to transform the intention of the capitalist to invest into reality.

However, in addition to such obvious reasons, others exist which are less obvious; for example, the time delay concerning information on market conjuncture. In other words, production anarchy under conditions of a good economy, as a result of which periodic crises of overproduction occur, leads to the fact that information required concerning the state of the economy is received by the owner-capitalist on the basis of conjunctures, expressed in prices, which have already occurred in the market. From this it follows that he finds out about a decline sometime after the drop in prices, and about increases sometime after the rise in prices for specific goods.

The duration of the capitalistic reproduction cycle thus coincides in time with the use of information concerning the state of conjuncture in individual phases of the cycle, expressed predominantly in market prices and coincides with the time required for its utilization in separate phases of this cycle. From this the inevitable drop in prices during a period of decline and their increase after a depression was a characteristic feature of the cycles in the XIX and beginning of the XX Centuries. Aside from other functions they also played the role of information for the capitalist concerning the state of the economic conjuncture. This also partly explains to us why there were never any identical cycles, since the state of this information, in addition to objective and constant factors, was influenced by a mass of additional factors of a subjective and even of a random nature.

Then what happened after the Second World War? First the broadening of a firm, guaranteed market occurred, which certainly exerted a definite influence on information movement. A guaranteed market represents firm reliable information or demand, notwithstanding random market processes.

Secondly, other sources of information appeared concerning the state of the economy in addition to information by means of price movements; these sources significantly outstrip information concerning the state of the conjuncture by means of price changes.

Due to economic and other predictions, and due to a carefully developed plan of mutual dependence of some branches of the national economy on others, the capitalist-owner and the state obtained information concerning the conomic position long before random price changes in the market. They are not, of course, able to change the production anarchy, since to predict does not mean to control, and production anarchy is explained not simply by the circumstance that individual owners do not know what others are doing, but by the basic contradiction of capitalism, private property, which forces each one to follow his personal advantage. More reliable and advance information therefore cannot eliminate production anarchy. But within known limits the possibility appears of taking several measures in advance.

One of the most important consequences of information acceleration is compression in time of individual phases of the cycle, since capitalists who are warned concerning, for example, a forthcoming decline will begin earlier to curtail production, and fewer will be in a state of uncertainty in a period of depression and upturn, and the more rapid will be the attempts to utilize the conjunctural rise. Naturally, the entire cycle is curtailed. However curtailment of the cycle apparently will be different as a result of different phases, because objective causes exist which determine phase duration. It is possible to make several conclusions which logically suggest themselves from this proposal concerning the role of information, which is speculative to a certain degree.

1. Curtailment of cycle lengths basically must occur at the expense of depression and recovery phases.

2. A drop in the production and in the overproduction of the commodity mass in a period of decline will be somewhat less.

3. The crisis of overproduction to an ever-increasing extent will be expressed not so much in the overproduction of the commodity mass, as in under-utilization of productive capacity.

4. Since curtailment of production will begin earlier than the drop in prices and independently of them, market prices will lose, to a significant extent, their value as information concerning conjuncture and therefore may be maintained at the previous level or even increased, if they are not disturbed by some other phenomenon.

These logical conclusions from the model coincide with the real position in the economy of developed capitalistic countries.

However, is not the proposed explanation of acceleration in periodicity of the cycle under the influence of information change and appeal to a subjective factor? Herein lies the difference between social processes on the one hand and physical and biological processes on the other, for in society objective causes, in order to act on the progress of phenomena, must in a preliminary step pass through peoples heads. The question of the nature acquired by this passage of information through peoples heads--whether it is reflection of conjuncture in market prices or in the form of economic prognoses or even something else--this is already an attendant factor.

The facts mentioned above do not exhaust, however, the influence of new sources of information on the nature of the economic cycle. The fact is that acceleration in the handling of information leads not simply to curtailment of periodic crises, but also to a specific phenomenon--the so-called bandwagon effect. This term, adopted from political vocabulary, literally designates the desire to find a place quickly in the train of that candidate who appears in advance to be the obvious victor in impending elections. In economic life a prognosis concerning an expected upturn in business activity produces the same "bandwagon" effect with investors. However, in order to find a place in this type of economic train during an upturn, since the course of the cycle is accelerating, it is necessary to buy one's ticket in advance. This means that in advance--not during the upturn or ascending phase, but even earlier--it is necessary to acquire productive capacities which may be utilized during the upturn. This partially makes clear to us why enterprises and entire corporations plan their capital investments a decade and even longer in advance.

Further, during the downturn phase another phenomenon appears which has received the name of "lines." Of course the meaning of this word is not the ordinary one, but rather an opposite and more general meaning. In contrast to an ordinary line of purchasers for goods, during a downturn a characteristic commodity mass line appears behind the purchasers. Anti-crisis measures may exert an influence on the nature of a similar "line." But these are not in a position to eliminate the phenomenon altogether. The fact is that a commodity mass accumulation which finds no market for itself is also explained by disorder in the distribution sphere, but originates mainly in the production sphere. In the first case certain palliatives may be employed more or less successfully. But as the solvent demand of the population under capitalism in general lags behind production capabilities, so the commodity "line", or overproduction, cannot be eliminated by any kind of anti-crisis measures. It originates in shortcomings in information circulation within the utilization sphere, and in the lack of solvent demand, i.e., of effective information within the system. Therefore a crisis can never be accompanied by replacement of commodity mass production surpluses by underloading of the enterprises.

This is still another example of how modeling permits us to obtain a deeper understanding of the objective course of social processes.

MODELING--A TOOL FOR PREDICTION AND CONTROL

N. Amosov, Member Correspondent of the Academy of Sciences of the USSR

During the last decades science has made a tremendous step forward. In particular we speak even today of the fact that it has the means which permit it to organize the life of the people in the best manner. This instance concerns modeling as a tool of prediction and optimum control.

Every concept represents modeling. When a man speaks, this means that "he knows", and that means that in the cortex of his brain there exists a certain complex of nerve cells, joined by connectives, in which a model as an object known to him is presented. The brain is a tremendous modeling device, capable of creating the most diverse models of systems of both the internal and external world. In this connection our sense organs perceive energy which arrives from external objects and codes this with nerve impulses, thereby isolating primary information. Then this information is transmitted to the brain and is subjected to processing, which consists either of the stimulation of already prepared models of gray matter cells--and here we are already dealing with the recognition process--or in the formation of new models, which reflect the concept and quality of the external world.

The overall complex of information processing in a computer is approximately the same. In preparing the machines for operation, specific basic information in programs for the solution of problems are placed in its memory. If information is now introduced into the machine concerning an object, the information is subject to processing in accordance with the existing program and as a result a new model is obtained--the problem solution. This model may be maintained in the memory of the machine for utilization in the solution of other problems or it may pass to the "output."

Analogy with the process of thought is not the single factor in the use of computers as a method of modeling. Any model is a combination of a number of physical elements which reflect the structure or the function of a certain system--the original. In this connection it is possible to divide arbitrarily the systems into static and dynamic (active) systems. For example, a drawing, figure, photograph or plan characterizes a system statically. Motion picture film gives us a representation of the dynamics of structural change and therefore of system functions. Thus in dynamic models not only the structure but also the functions of a system are reflected in the form of a change in its construction and energy with time. Not very long ago dynamic models were presented in the form of mechanical toys. Now the position is changed due to the appearance of computers, which permit us to reproduce dynamically the interaction of all elements of models of comparatively complex systems.

Under complex systems we may arbitrarily include systems which consist of a very large number of different elements, interconnected with each other in such a way that they may function as a single unit. In practice these are systems "of the living type", and the cell, organism, brain and finally even society may serve as models of the systems. Our contemporary methods of modeling are not sufficient to reflect the entire complexity of similar systems. In fact, the human brain, thus far the most highly perfected of modeling devices, consists approximately of $14 \cdot 10^9$ cell-elements. Naturally it is not in a position to reflect with completeness the structure and function of such a complex system as the human organism which consists of approximately of 10^{27} atoms.

From this the question arises immediately concerning the completeness of modeling. In practice, for each complex system, it is possible to construct an infinite number of models, since they will be to a certain extent simplified and distorted reflections of the original. The degree of simplification depends on the complexity of the object and the capability of the modeling mediums: of a number of nerve cells in the cortex of the brain or physical elements in the machine memory. Since the activity of a complex system is characterized by structure and by functions (by programs), the completeness of a model may be characterized mathematically by the ratio of the reproduced programs of the original to their total number. For example, even the simplest living beings are characterized by such programs as reaction capability, adaptability, capability for motion, growth and reproduction as well as variability. Therefore the simplest model of such a being will possess only reaction, a more complex model must add to this adaptability to environmental conditions, and a still more complex model must include gross and reproduction and finally the most complex will acquire the capability for mutations.

With a certain amount of assumption we may isolate three basic types of models. The first are complete (or more exactly, arbitrarily complete) models, which reproduce all the basic programs of the original. The second type includes generalized models which reflect certain total characteristics of objects. If, for example, we imagine that the content of a book is a complete model of certain events, then a short abstract will be a generalized model. A description of personalities, characters, and individual episodes--these are all partial models. Thus the third type--the partial models--reflects one of the programs or one of the properties of a complex system. We must add to this the fact that each of these models, taken as a physical structure, may again be modeled, thus erecting in this manner "multi-story" models with various degrees of generalization.

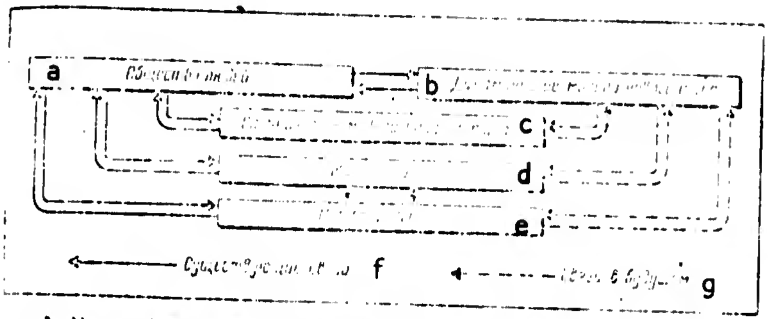
Unfortunately our capabilities for the modeling of very complex systems are still extremely limited. Of course, theoretically it is possible to imagine a complete model of society, for example, in the form of a certain aggregate of machine-robots, functioning in real time. However there is no basic concept for the creation of such a model, even if the monumental technical difficulties connected with this could be overcome. The use for such a model would hardly be great, if the people in it were modeled in a simplified manner, then society would quickly outstrip the model and, on the other hand, if the robots were given a creative program then the model would begin to develop by itself and its paths would again differ from those of society.

However, all these considerations are groundless: for the present it is difficult to develop a complete model of even a single man, let alone an entire society. Therefore even with consideration for future prospects, it is worthwhile to discuss only certain kinds of generalized models and partial models of society, which do not pretend to complete representation, but nevertheless characterize the quantitative side of the interrelation of its individual elements. Such models will be dynamic (active) models of society.

The "World" System and a Model of Man

People live in a world of nature and things created by them, the number and diversity of which grow catastrophically. Therefore as applied to the modeling problem, it is expedient to speak not about man as himself, but as a certain "world" system, which includes, in addition to the society of people, the world of nature and the world of things (technology). In addition, it is also expedient to include in this system as independent elements static models of an old world in the form of books, drawings and diagrams and also dynamic models of a new type of world, represented by electronic devices and computers. For the present all the links of this system are associated with each other only through people. But in future dynamic models, apparently, we will have direct links with nature, with the world of things (technology) and with static models.

A society of people in the person of a certain abstract man is the basic link in the "world" system. Therefore one of the most complex tasks in the problem of modeling and control of the development of society is the creation of a generalized model of man, which reveals the basic regularities of his behavior.

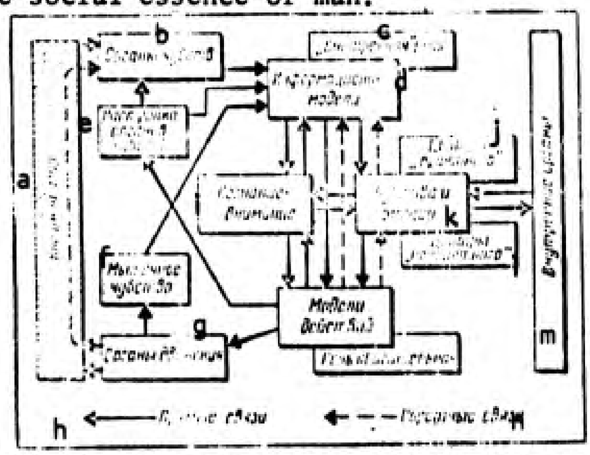


A Hypothetical Diagram of a Model of the "World" System. Key: a, A society of people; b, New dynamic models; c, Old static models; d, The world of things; e, The world of nature; f, Existing links; g, Links in the future.

From the standpoint of cybernetics a man may be represented as a certain automaton with an assembly of complex and even contradictory programs, which are placed in operation depending on external and internal conditions. These programs may be arbitrarily divided into three types: "self" programs, the basis of which is the instinct of self preservation, programs "for the species", which reflect the sexual and paternal instincts, and programs "for society", which characterize man as a member of society. Of course these are only basic programs, each of which consists of a number of sub-programs, directed toward the achievement of temporary or specific goals.

The hypothetical model of man (or to be more specific, his psyche) may be represented in the following manner. The external world acts on sense organ receptors, the effective operation of which is provided for by a special tuning assembly. The sense organs code the energy of these actions in nerve impulses and transmit these to the "information models" block, in which recognition is accomplished by means of the excitation of corresponding models. These models may be formed in the process of teaching or of inherent creativity and reflect the images, concept qualities and changes with time of the most diverse objects and pictures of reality. A special place is occupied by "internal" speech--information models in the form of a characteristic code, which proves to be very convenient for the description of complex abstract phenomena which are not subject to real perception.

From the "information models" block the stimulation is transmitted in several directions. The signals arrive first of all at the "feelings and emotions" block, where models of natural feelings and their derivatives are located, which are based on instincts and complex reflexes. Using the categories of mathematics, we may say that each feeling has a plus or minus sign, depending on whether it is "pleasant" or "unpleasant". Part of the centers of this block are under the constant influence of the internal sphere of man--sensations of cold, warmth, pain and hunger. Another part reacts on the so-called secondary feelings, implanted by education and reflecting the social essence of man.



A Hypothetical Diagram of the Model of a Man. Key: a, External world; b, Sense organs; c, "Internal" speech; d, Information models; e, Sense organ tuning; f, Muscular sense; g, Organs of movement; h, Direct links; i, Consciousness-attention; j, "Pleasant" centers; k, Feelings and emotions; l, "Unpleasant" centers; m, Internal organs; n, Feedback links.

The information block is connected with the "action models" block, in which muscle control programs are concentrated, in the form of a set of models of various motor acts and processes. The selection of a specific motor program is determined by influence from the "feelings and emotions" block, after which it is realized with the aid of the organs of movement. The correctness of the selection and realization of the program is controlled and corrected by the "muscular sense" and "sense organ" blocks. The first of these establishes whether the movement accomplished is in accordance with the initial plan established in the model, and the second establishes to what extent the effect corresponds to the proposed effect. For example, the perception by a man of the unpleasant fact that he is sinking "switches on" a program of arm movement. The "muscular sense" block signals that the man is waving his arms while the sense organs establish how effectively this chosen program is supporting him in the water and whether or not it is necessary, for example, to make these motions more often.

The third excitation transmission path leads to the "consciousness-attention" block, the role of which we shall discuss in greater detail.

Man is surrounded by a huge world with a mass of subjects and situations, which influence his sense organs. Naturally, he is simply not in a position to perceive and to comprehend all of the information which arrives from outside--this would immediately excite almost all available models in the cortex of the brain. Therefore a selection is made: first, as a result of direct tuning of the receptors on the part of the "consciousness-attention" block, and the second as the result of the difference in excitability of the models themselves.

Excitation of the model is characterized by the activity of the neurons which form it, and therefore it may be very different--from the minimum (independent activity) to the maximum. Therefore the concept "model excitation" includes not only the fact of activity itself, but also its level. In addition, excitation (activity) is characterized by the parameter which involves duration of the "aftereffect", which depends on the amount of use of the information channels (links) between neurons both within the models as well as between individual models. The maximum possible level of excitation and maximum use of the links are attained as the result of training--frequent use of the model and the link--and are maintained as model parameters during a period of reduced activity (rest). Training is based on this property. Finally, each model is characterized by a basic excitability--a readiness to pass to the state of excitation. Excitability may also be negative, and then we must deal with inhibition.

Excitability (inhibition) and the level of activity during a period of model excitation are regulated by the "consciousness-attention" block. Its simplest function at every moment is to intensify the excitation of one model and to inhibit the excitation of all others. Thus a "thought" arises: one model, i.e., the one which is the most important at a given moment, is isolated from all the others. A hypothetical property of the amplifying system is that it quickly "tires" and after short time intervals is forced to switch to another model, which at a given moment is isolated as being the most active among all the other models. This model may be excited either from the external or from the internal sphere of a man, or, simply because it has been frequently utilized in the recent past and is well trained. Thus the progress of a thought--"thought flow" arises: the switching of an amplifier from one model to another, then to a third, etc.

It should be noted that information processing is accomplished not only on the conscious level, i.e., in amplified models of the brain cortex, but also in the subconscious, or in the subcortex. It is known, for example, that even the most complex motor acts, if they are already well developed, may be accomplished without attracting attention. It is true that information processing progresses less intensively, but its essence also consists in the transmission of excitations along links from certain models to others. The sphere of the subconscious is quite important; much information is processed in this area, material is prepared for the conscious level, and most of the sensations from the external organ pass through it.

The diagram of brain functioning and the psyche of a man described above may be reproduced in an artificial modeling device. The difficulties which arise in this case are more of a technical than of a fundamental nature. The complex matter in this connection consists of modeling the programs which characterize man as a member of society. Any man to some extent is characterized by three qualities: "narrow-mindedness", which is a shortcoming of the models in reflecting the entire diversity of the environment; "subjectivity", which is a distorted reflection, depending on attitude toward an object and "fascination capability" (hypertrophy), which imparts excessive value to a certain model with frequent usage.

The latter quality presents a certain amount of interest. A man appears in the world with an assembly of innate programs, or instincts of self preservation and preservation of the species, which are based in the subcortex and in the endoctine system. The cortex in this case is relegated to the role of a medium which provides a choice of the best variant for the realization of innate programs. But the structure and function of the cortex of the brain as a modeling device are such that they permit imparting to it new programs which transform man into a member of a more complex system, which is society. A physiological basis for this property is contained in the inclination of the gray matter cells toward hypertrophy, which is an intensification of functions of a specific model in connection with frequent and purposeful training in the process of education. The result depends on the effectiveness of the latter, i.e., to what degree the cortex is transformed from a tool of the subcortex into its own master.

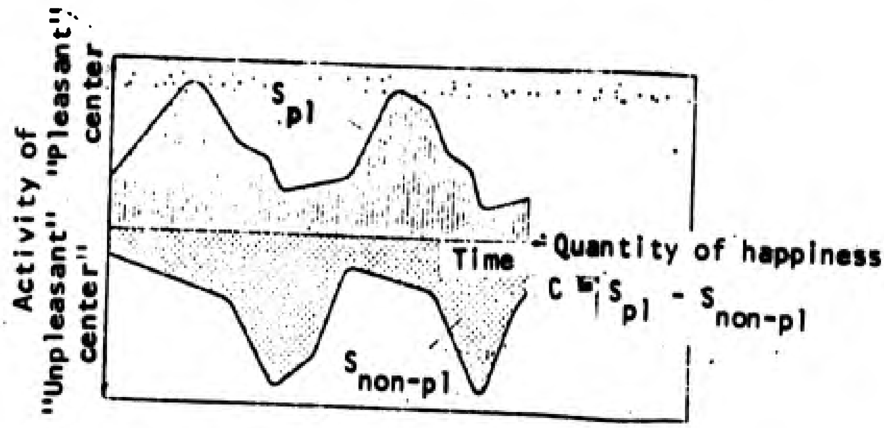
Social education also imparts to man such social programs as concepts of duty, conscious and truth, ideals of faith, and a capacity for creativity. The development of similar programs may be traced by using as examples such interesting and important categories as "truth" and "faith". Models of the external world may be divided into two groups: those obtained as a result of direct perception of phenomena by the sense organs and those constructed on the basis of verbal description. The coincidence of both these models is perceived as a pleasant sense of "truth." This is also carried over to the source of the verbal information--for example, to the teacher who proved the validity of his explanations with experiments. After this the teacher becomes an authority and his subsequent verbal information is also perceived as truth which requires no proof. This information automatically becomes a part of experience established by true models and further may serve as a criterion for the evaluation of other verbal descriptions.

In the same manner faith is an extrapolation of truth through authority, a non-proved perception of verbal information as truth. It is determined by one of the basic programs of thought--"the program of trust" and is acquired with speech. This program may become weakened as a result of errors and disappointments, and then another program appears--the "program of doubts", which is required in order to reinforce the words of experimental proof. Both the former and the latter programs are extremely important for a man as a member of society. In the final analysis the problem of modeling and control is reduced to a distinctive "projection" of an optimal society, the constant features of which must obviously be the happiness of its members, stability and capability for development (progress).

The "degree" and "quantity of happiness" are measurable values. The "feelings and emotions" block of the cortex contains "pleasant" and "unpleasant" centers, the excitation of which in the course of a specific time segment is expressed by the difference in integral areas, bounded by curves. It is true that the same external stimuli do not always generate identical "pleasant" and "unpleasant" feelings. If the stimuli act constantly or very frequently the phenomenon of adaptation (the act of becoming accustomed) interferes in this process and the sharpness of the senses is dulled. For psychology the latter phenomenon will become a future problem, the essence of which consists of the necessity of finding an optimum content of pleasant and unpleasant stimuli, which will permit obtaining maximum satisfaction and avoiding boredom and monotony.

The problems which sociology must deal with are complex ones. Many innate programs are egotistical and the satisfaction of one man may be bought with the grief of others. Therefore society must be organized in such a manner that with the help of education and limitation, anti-social tendencies are reduced to a minimum. As a result the necessity arises for careful study and classification of innate programs (instincts and reflexes), of direct and derived feelings associated with these considering their effects on society, on the one hand, and an evaluation must be made of the possibilities of suppressing negative and amplifying positive programs, on the other hand.

In a first approximation it is possible to attempt to imagine such a classification today, although of course it will reflect only the qualitative side of the question. In order to construct models of man in the broadest meaning of the word (with characteristics including a capacity for education, adaptation, and with behavior programs) each of the points in a similar classification must be expressed by exact quantitative indicators which may be obtained as a result of broad psychological and sociological investigations. In the final analysis this will permit us to obtain for each innate program a graphic or mathematical characteristic which reflects the relationship of training influences required for the suppression or amplification of a given program.



Hypothetical Diagram of an Evaluation of Quantity of Happiness.

A Model of Society and the Future

From a modeling standpoint, society represents a complex system, and in order to intensify our concept of it we require models which reflect the phenomena which occur in society not only qualitatively, but also quantitatively. The development of similar models, even as a prospect, will present a rather difficult problem; one of the approaches to the solution of this problem consists of dividing society into a number of "closed" subsystems, through the model of a man, such as "state," "idealogy and politics", "economics", "science", "education and training" and "art." Naturally the division into subsystems has the features of a certain arbitrariness, since there are no clear boundaries between them. But this is required: each modeling operation is associated with a certain simplification, included within the sequential isolation of more important information or, in other words, in a discrete (in stages) expression of continuous processes.

The modeling of any of the subsystems enumerated is characterized by general features which touch upon the scope and essence of the models realized. If these models are coarsely divided into simple and complex models, then the former must be characterized by formal structures with simple codes for information exchange. These will be models which reproduce the structure of a network of organizations and institutions reflecting the presence of education, facilities, quantity of work, content of generalized characteristics of the performers and which consider the influence on their professional activity of various stimuli. The development of similar models is the simplest problem variant.

Complex models must reproduce not only the structures and functions of the subsystem, but also their essence: the psychology of the participants, the content of ideas, theories and hypotheses, controversial problems and general interests. Here there are no fundamental limitations--in the final analysis the content of any word description which reflects a theory or even an idea may be expressed by a structural model with specific element functions. This model will "act" in accordance with programs which issue from the structure and the characteristics of elements and external actions.

All such characteristics of subsystem models and mainly models of human psyche force us to assume that the problem of modeling such a complex system as society will initially be solved in the form of an extremely complex diagram, which will be calculated on whole complexes of gigantic digital machines. Later, probably, a new technology will be founded for the development of artificial "neurons" and methods will be worked out for the synthesis from these of complex structures in the form of analogous modeling devices.

Such models may be used first of all for such purposes as managing the economy, and subsequently for control over education and even the policy of the state. It is well known that a complex system may be transformed from one state into another by several paths. In this connection the more complex the system, the greater the number of possible variants. Naturally it is desirable to select from these the most advantageous or optimum variant. For this purpose, having a model of a complex system, we must establish for it a basic real and desirable final state, and then "calculate" how the system structure and function are to be changed with time.

To choose an optimum variant for the transformation means to curtail time, sacrifices and efforts. Since the process of the transformation is accomplished with the aid of controlling influences, the latter must be of maximum effectiveness. In principle the controlling influences may be external, for example, in the teaching of a child and the curing of illnesses. But external controlling influences do not exist for a system of the type represented by society. In this connection questions of the control of a complex system from inside acquire special importance, and as a consequence modeling requirements are raised primarily in such a system as a "state."

The structure of the "state" subsystem may be reproduced in the form of a combination of models of such performance elements as central government, local controls, juridical elements, armies, organizations for education, public health and social insurance. By governing from general positions limited by a constitution, and through legislation and traditions, these organs accomplish programs appropriate to them--from programs of development and security to programs of education concerning limitations which protect the interests of society from the acts of citizens who have gone beyond the limits of the law. The effectiveness of the realization of these programs is controlled by feedback links, i.e., information which proceeds from the controlled objects.

Problems which are solved by the "state" subsystem are extremely complex--even if we accept only three positions as optimal criteria: these are the happiness of most of the citizens, stability and progress. The reconciliation of these positions is difficult. For example, stability may be obtained at the price of restrictions but here happiness and progress suffer. In running after happiness and permitting excess freedom, we may cast aside progress and go beyond the limits of a stable state since enthusiasm is a characteristic of the people.

Therefore in a model of the "state" subsystem, we must find a reflection of a definite conservatism, which appears in the stability of the laws, in combination with intelligent variability, which is involved in the improvement of the laws as society develops.

The goal of modeling the "state" subsystem consists of the optimization of the most diverse forms and methods of managing the country. In the future, for example, the question of the determination of a share of personal and public property may become one aspect of modeling. With the development of society the production of material goods will increase many times. On the one hand, this will lead to an increase in well being, but on the other hand, we cannot exclude the danger that greed, like rust, will undermine the morale of the least stable elements of society. Thus, this may generate a requirement to establish certain standards for personal property (possible for a certain period of time only), while the satisfaction of a greater amount of personal needs will be accomplished at the expense of public property.

The "state" subsystem is closely associated, on the one hand, with the "idealogy and politics" subsystem. The model of the latter with a certain degree of strictness may be presented on the basis of the fundamental positions of Marxist-Leninism or in more detail, on the statements of the Party programs for a specific length of time. This also may be the most complex model, which reproduces the structure and programs of a hypothetical society, controlled by these positions. The use of such models permits us to determine the optimum forms and methods for struggle on the idealogy front.

On the other hand, the "state" subsystem comes into close contact with the "economic" subsystem, in which all people participate, some as producers and others as consumers. The models of this subsystem must reflect all goods and machines, factories and installations, financial and production documentation, and the scope and form of information exchange. The use of such models permits us to optimize control of the economy, secure the best distribution of means and efforts between the private and public spheres of life, and between the "science", "art" and "education" subsystems.

The modeling of such a subsystem as the "science" subsystem is considerably more complex. Even the formal reproduction in the form of a structure of a net of scientific institutions, of their equipment, staffs, of technical and material facilities, is associated with a great deal of difficulties due to the tremendous quantity of information in circulation within this subsystem. An attempt to reproduce the content of science in dynamics--to reflect its facts, theories, hypotheses, disputes and conclusions--would require the inclusion of a still more powerful modeling technology.

Such complex models may be employed with the aims of predicting the future of the subsystem itself. With such models it would be possible to establish the initial state of the subsystem, the internal and external influences, and then "calculate" how the functions and structure of its parts would change with time. This aspect of the problem of modeling is extremely interesting, although the possibilities here, unfortunately, are limited: in models it is difficult to reproduce and to foresee creativity; therefore every prediction has a probability nature. Nevertheless this does not exclude the possibility of attempting to "calculate" the future of subsystems, even if this is within the limits of specific periods, or to utilize models of a subsystem for the "generation" of new ideas, theories and hypotheses.

To a great extent the difficulties cited are also characteristic of modeling the "art" subsystem. This subsystem contains many subjects, including works of art, which are exceedingly complex articles to express in models. Therefore here we are apparently forced to limit ourselves to formal models which reproduce the subsystem structure and which in a certain generalized form reflect the essence of art, its ideas, content and form. Nevertheless even such models may be used as the means which will permit us to "project" measures for the improvement of the influence and educational aim of art.

Finally we come to the "education and training" subsystem. Its model must reflect not only the existence of structure and function in the form of a network of educational institutions and their staffs, as well as teaching means and methods; it must also include consideration for the educational capabilities of the new technology, e.g., television or teaching devices. In addition, the fact must also be reflected that with an increase in well being and culture, the educational capabilities of the family will be steadily raised. It is true that the society of the future can hardly reconcile itself to the fact that work which requires not only heart but also knowledge is entrusted to the least qualified educators--parents. This does not mean that the children will be isolated from their parents, but that the share of public participation and control in the education of children, obviously, will increase by many times. All of this will permit the organization of programmed teaching and education with an individual approach, based on modeling with consideration for the personality characteristics of each child.

There is no doubt that the development of society will be accompanied by an ever-increasing role on the part of science. In this connection since "happiness" is a psychological concept, one of the leading places will be occupied by social psychology among the sciences of the future. Its primary task will be the development and undeviating improvement of the "complete" model of the human psyche; by virtue of this fact, various social-psychological experiments will acquire great importance in the life of society. With their help generalized, physical models may be developed with consideration for sex, age, geographical origin, profession and position in society. Simultaneously these experiments will permit us to obtain information on which to base judgments concerning the welfare of society and to "project" social-economic measures which will lead to further progress. The role of instrumental psychology will also increase in the future, including in particular the role of neuropharmacology in psychic control.

It seems that this is perhaps the place to put the period, for any prediction, even with the use of modeling technology, has a probability nature. We should say only that if the technology of the future expands the possibilities of control, then science will bring it to the optimum point. Armed with modeling methods, science will thus permit all planning measures to be first "played" on models, and then will check their effectiveness in limited experiments; only after this will they be applied in life under the constant control of feedback links--information which is obtained mainly from the "service of social psychology". Science is not only a theory or a collection of models. It is also the practice of the control of the most complex systems. Its highest purpose is the service of people. We may count upon the fact that it will help them to create not only material goods, but also methods for the scientific control of society.

LINGUISTICS AND PRACTICE

Doctor of Physicomathematical Sciences R. Dobrushin

A period of essential changes has arrived for linguistics, which is the science of language, just as for many other sciences. First of all this has been brought about by the fact that with the appearance of cybernetic technology, the sphere of the application of this science has broadened considerably.

In fact, previously the basic applications of linguistics were associated with the use of languages by man, for example, in teaching native or foreign languages. This determined the nature of linguistics as a humanitarian science.

With the appearance of electronic computers the problem arose of communication between man and the machine. It is more convenient for a man to express his ideas in a language format, and therefore it was necessary to teach the machine directly to perceive and to process verbal speech and texts in the natural languages of man. This complex problem has still not been solved. One of the most important reasons for this is concealed in the contemporary state of linguistics.

It is possible to name four fields of cybernetic technology where development is being held up as the result of lagging in the science of language. First of all there is the well-known problem of machine translation from one language to another. The work of recent years has revealed that although this problem has been solved unconditionally in principle, it is more difficult than it appeared at first glance. The difficulties here are not cybernetic, but are linguistic. In order to achieve success, first of all it is necessary to have a much deeper understanding of the grammatical and in particular of the meaningful structure of the language than has been achieved thus far.

In connection with the unbelievably rapid increase in the volume of knowledge accumulated by humanity, the problem of the development of informational cybernetic devices which store and search for scientific information on request became particularly pressing. For this purpose it was necessary at first to "teach" the machine to perceive information written in a natural language. However, the translation from ordinary language to machine language rests upon lagging linguistic theory.

The problem of machine "stenography" is very important, or, to put it another way, the problem of the perception by the machine of verbal speech. The solution of this problem would permit us to control machinery by means of the voice and, as is known, voice reaction is the quickest and most natural reaction of man to a changing situation. The problem here consists of a lack of study of the phonetic-acoustic side of language.

Finally, the avalanche-resembling increase in the quantity of conversations over communications channels forces us to search for means of speech compression. It is necessary to learn to isolate the essential features of speech so that in transmitting these over communications channels, the speech in its initial form may be restored at the receiving end. This would permit a significant load reduction in communications channels. In order to solve this problem a deep understanding of the statistical properties of speech is required from positions of information theory.

In a word, an intensive study of the laws of speech is required. However, when cybernetics and technology encountered linguistics, it appeared that the contemporary level of the science of language did not correspond to their needs. What was the reason for this? It is known that the language of mathematics is the language of contemporary cybernetic technology. Therefore in order to solve technical problems it is necessary to be able to describe the qualitative and quantitative regularities of language on the same level of logical depth and fullness which can only be achieved by mathematics. Here the matter does not involve individual corrections which might be introduced into the methods of contemporary linguistics, nor does it involve a supplementary study of individual particular problems. It is necessary to refine or to reexamine the solution of almost all fundamental problems of linguistics and, moreover, it is also necessary to solve problems which previously could not even be raised.

Notwithstanding the practical demands raised in connection with the appearance of electronic computers, internal processes in the development of the science of language itself have led many linguists to the realization of the necessity for fundamental changes in the technique of their investigations. The representatives of the direction conveniently termed structural linguistics are closer than others to an understanding of the new problems. It is important to emphasize that the structural approach to language took shape in a natural manner at the roots of linguistics itself as a result of an intensification in the understanding of the nature of language. Characteristic of this direction is the clear delimitation between the meaningful and formal sides of language. Its representatives understand the fruitfulness of the study of the form of language, notwithstanding the history and meaningful content of these forms, while utilizing for this purpose the achievements of mathematics and natural sciences.

The new linguistic methods have also proved to be useful in the classical problems. For example, the use of mathematical methods in an analysis of language permitted us to formulate more exactly several rules of grammer and orthography. Of course it would be wrong to maintain that the classical methods have become obsolete for all areas of linguistics. Thus in a study of language history the application of mathematical methods thus far is only of secondary importance. However there is no doubt that at the present time the mastery of mathematical methods must be a required element in the scientific education of every linguist to a degree not less than for an engineer.

3. CYBERNETICS UNEXPECTED

EXCURSION INTO TERRA INCOGNITA

INFORMATION SIGNALS AND THE PROBLEM OF ARTISTIC VALUE

Candidate of Philological Sciences Yu. Filip'yev

The situation in contemporary esthetics and poetics is such that we have no exact presentation of many concepts. Therefore prior to the application in certain esthetic fields and in the study of art of mathematical methods, it is necessary that we clarify the nature of these basic concepts, including, for example, the nature of esthetic efforts, which transform the figurative thought of the artist and the poet into what is called esthetic values.

In this light the task of my article is not to determine quantitatively the accuracy of the relationships of certain esthetic information elements in certain works of art, but first of all to uncover the material essence itself, the material basis of esthetic organized efforts, while showing (and not merely asserting in a declaratory manner) that this basis is signal-informational.

It may be maintained with complete correctness that the scientific materialistic solution of the question concerning esthetic organizational efforts and concerning their nature at the present time for esthetics is more serious than quantitative approaches to the relationship of esthetic information elements of certain works of art.

I understand, however, that from the point of view of the technical and mathematical aspect of the theory of information, articles which reveal the relationship of esthetic informational elements in certain works of art present a great deal of interest. But they present this interest only for specialists in the mathematical aspect of information theory. For esthetics itself, the qualitative approach to problems of esthetic and artistic efforts is at the present time more important and pressing than the quantitative approach. This cannot be doubted if we consider the state of affairs in contemporary esthetics.

In addition I am inclined to think that in these questions we must consider the extremely curious statement of Academician A. N. Kolmogorov that "The exceptional enthusiasm which is predominant now for the reduction of all questions to a calculation of information quantity must be replaced by searches for a fuller characterization of various types of information, while not ignoring their qualitative aspect."

This is a very remarkable conclusion which indicates that even the representatives of the mathematical aspects of cybernetics themselves understand the necessity of approaches toward the analysis of informational processes from the point of view not only of their quantitative aspect, but also from the point of view of understanding the qualitative peculiarities of the informational structure itself of certain processes.

The special material essence of the control pulse phenomenon has appeared within the concept of the cybernetic signal. The effect of a signal is completely incommensurable with its inherent energy.

Cases exist when a signal displays energy which is not less, but is rather several times more than that of the events with which the pulse is associated. For example, a Geiger counter registers with an electrical current pulse the path of cosmic or radioactive radiation particles. The energy of these pulse signals exceeds by many times the energy of the particles themselves.

But phenomena are very frequent in which the signal causes the occurrence of energy processes of high power. For example, the pulse applied to the control grid of a radio tube is very small in comparison with the energy of the entire system, but nevertheless this pulse is capable of "commanding" the entire radio tube plate current.

Of course, signal always exists in a certain physical embodiment, including the mechanical motion, radio waves, heat, sound, light, etc. But a signal which exists in nature is not in itself the physical object in which the signal is embodied.

The same signal may have several quite different material carriers. But for signal meaning and effect this is not significant. For example, the same words of speech may be recorded on magnetic tape and on a phonograph record, transmitted by telephone or with the aid of electromagnetic radio waves, or may exist in written letter form, etc. Although their physical carriers in a given case are quite different, their informational meaning remains the same. The codes in which this meaning resides and is maintained are different and may be transformed from one medium or form of energy to another, but the "meaningful information" remains the same. Here so-called informational isomorphism of signals occurs, i.e., a similarity in sense and content of action, but not in the material or energy state. "Information is information, and not matter or energy," emphasizes N. Wiener.

The essence itself of the signal pulse is not in a clear "quantum" of matter and energy with which the pulse is associated, is not in the code in which it is expressed, but, as stated by the German philosopher G. Klaus, it is in the "semantic, informational sense" of the signal, in that the signal, in entering a certain system is capable, as if setting the system in motion, of freeing all of the potential energy within it.

In this scheme the signal represents a dynamic beginning and acts as a sort of "primary impetus" for such systems, which are incapable of action and self development prior to signal introduction.

In this case the signal acts not in accordance with its material and energy characteristic, but in accordance with its semantic value. It could not be otherwise, for prior to its action the signal and its structure are isomorphically transformed so that nothing remains from the former material and energy state. This is why only the semantic value is active in the signal and in its structure.

Such a contemporary concept of informational signals is very important in attempts for the sequential solution of certain basic problems of esthetics and artistic creation.

At the present time the problem has been placed on the agenda of analyzing what artistic value consists of, and what forces are active within it. Obviously we must first of all approach the nature of artistic value from its active side.

In this sense such cybernetic concepts as signal and information obviously must help us in discovering the internal organizational forces of artistic value.

However, having introduced the term "information" into the study of art, certain esthetes attempt to construe this to mean only that which has been called the grapho-factual side, i.e., only those specific facts which are reflected in works of art.

However, artistic and esthetic information cannot be understood in so trivial a manner; it is known that grapho-factual material in artistic works is organized and mastered in a special way. In the task of esthetics as a science is the comprehension of that which inherently makes the artistic image not only a grapho-factual repetition of certain living phenomena, but also transforms it specifically into artistic, esthetic value and infuses it with internal living forces, "imparts movement to life", according to the catch-words of Balvac.

The idea that the concept of artistic information designates only the grapho-factual side of works of art is associated only with with the pre-cybernetic concept of information, which reflects factual communications specifically.

The contemporary idea of information is of greater capacity and it therefore includes, of course, the particular case and the former concept of information, but mainly it expresses the capacity of certain systems for a specific type of structural organization. In this sense the concept of information contradicts the concept of entropy. "As entropy is a measure of disorganization, so information signals transmitted in a series are a measure of organization," stated N. Wiener.

Such a contemporary idea must also pertain to artistic information.

Esthetic information signals must play a tremendous role in this plan for the entire system of artistic thought.

The higher we climb in the degrees of development of natural phenomena in their gradations from the nonliving to the living, the more complex matter is organized, and the more often we encounter the signal form of interrelationships. The signal form of interrelationships acquires even greater significance for living beings in connection with their evolutionary origin from lower to higher forms.

In this connection it is curious to note that a specific structural combination of colored spots and lines unified with a surrounding background or a certain structural sound combination, i.e., those things which we, as people, often call elementary beauty in nature, are for the living world characteristic pulses organized as signals. Of course, living beings do not experience this effect specifically as the effect of beauty, but experience the "signal-acquiring" force of this action.

In the "songs" of certain birds we distinguish "calling songs", "seductive songs", and "threatening songs". Each "song" is a complete and self-sufficient complex structure which differs from another "song." Each such complex structural signal of the "song", which enters the living system of another bird, is capable of inwardly tuning the bird for specific behavior.

Each "song" separately fulfills here a role of a certain type of "signal key" for "winding" the living system of the birds for specific behavior and action. The signal is not a monosyllabic pulse, but possesses a specific structure.

It is important to note that when the structural combination of harmonies, colors or rhythmic motions acts on living beings as signals for certain behavior, these signals are perceived by the living beings not in their direct, material state, but are transformed into a state or code of a sensual, psychic stimulus. But even in this code they preserve that structural composition which they also had in the material code of natural phenomena. This is also structural isomorphism, or an isomorphically repeated structure, which is capable, as if "in its own image and likeness," of "winding" the system of the living being for specific behavior.

In the pre-human stage of the development of living nature, there was no consciousness and emotional life in the exact meaning of the word. Therefore the active signal structures in nature itself were capable only of directly and "rigidly" guiding living organisms toward appropriate behavior.

When due to the development of the first primitive tools of labor the process began of the transformation of our monkey-resembling forebearers into man, then gradually, as Marx wrote, appeared the "object-oriented development of the wealth of the human being" and for the first time a wealth of subjective human sensuality began partial development a musical ear, an eye sensitive to beauty of form, or in other words, those feelings which are capable of human enjoyment."

Differentiated and sharpened sensations developed in man of the multi-sided properties of the surrounding object world, and those properties which could act on human perception as structural-organizational factors multiplied.

But without tracing the forms of signal action in nature, including the signal action of elementary beauty, we cannot trace materialistically the origin of the human capacity to feel the attracting and organizational force of beauty as one of the natural forces.

Beauty becomes for people a strength, which awakens, in the words of Gor'kiy, "wonder, pride and joy."

Neither elementary beauty in nature nor beauty in the creativity of man acts on us "purely materialistically," nor generates within us any kinds of feelings of need or longing.

In this connection one of the main points in the history of esthetic thought has been the question of the non-consumer effect of beauty and esthetic values. This question was a stumbling block for both materialistic and idealistic esthetics. Not without reason did Kant state among his outstanding antinomies (unresolvable contraditions) the question of the so-called lack of personal interest in the effect of beauty.

Notwithstanding the entire metaphysical absolutization of the moment of "lack of personal interest", Kant correctly noted that beauty does not act as a force of consumer attraction to an object ("an esthetic evaluation is not directly a consumer evaluation"). But to call this consumer effect "lack of personal interest" is possible only in a relative sense. The fact is that although beauty and esthetic value carry no consumer-utilitarian use, they nevertheless act on man no less intensively, but in another manner: they create the characteristic, direct organization of perception and attention.

In contrast to ordinary satisfactions and enjoyment, the enjoyment of beauty and esthetic values is an intuitive admiration. Esthetic enjoyment is unselfish.

If it touches our esthetic sense, we would not dream of transforming, let us say, a birch forest into firewood. On the contrary, it gives us joy to see its thin, delicately glistening columns with the blue haze behind them, and the play of light in the whispering leaves.

Having entered our perception, beauty and esthetic values act as an organizing pulse for the appropriate arrangement of our spiritual world. Here this is expressed in the special signal-organizing nature of beauty and esthetic values.

The meaning of signal organization is qualitatively quite different than we saw for the meaning of material of energy interrelations. The difference in this case is great, while the effect is not less.

We are convinced with our own eyes that the approach to the signal-organizing sense of the effect of beauty is capable of explaining also the entire special material base of this effect and in addition to solve that antinomy "allegedly of no personal interest", which Kant raised.

It is specifically in this problem of the non-consumer effect of beauty that materialism and idealism in esthetics cross swords.

The signal-informational point of view is strong in that it may give an explanation for the functional properties of beauty in nature, in life and in the artistic activity of people, while at the same time it may raise the question anew concerning the material carrier of beauty--one of the forms of informational inter-reaction.

The organizational role of beauty will become clear and dynamic. It is beginning to act as a characteristic, directing and organizing stimulus.

In occupying themselves with living and productive activity, people develop in conjunction with this those stimuli which have an optimal-organizing sense for their lives. Consciously or spontaneously people find the means in order to reduce the chaos of living perceptions and to increase the organization itself of impressions from activity which surrounds them. Among these means of human self-assertion in the world, a great role is always played by all of the possible esthetic values created by people.

Although in nature and in life there are not really very many structural combinations of colors and sounds which may, in passing to an isomorphic state, become characteristic signal organizers of the psychic world, nevertheless people have constantly encountered and do encounter such phenomena in daily life.

The experience of such encounters is fixed in certain sections of human memory, although it may only be intuitive. Exceptionally gifted natures are particularly sensitive to this.

Artists capture the appearance of all possible esthetic signals which arrive from objects of nature or from some other objects of the creativity of people. They absorb these signals within themselves and infuse their creativity with them.

In the accomplishment of the signal-organizational foundation, the art masterpieces of antiquity, in any case, do not yield to later stages of the development of art. The solution of this phenomenon is concealed, apparently, in the structure itself of the expression of thought by the ancient peoples. Primitive thought confirmed not the formal-logical side of a thoughtful reflection of reality, but was such that it attempted, as noted by Gor'kiy, by the very force of a word, and by the force of expressiveness to influence phenomena of nature which oppose people. Although such a form of thought was applied to external, natural phenomena, in its reflection in the consciousness of the people in the environment, it was capable of giving the entire force of its expressiveness to the consciousness and will of the people.

In the subsequent development of human consciousness and forms of high-principled expressiveness, this method of thought construction gradually yield its place to the rationalistic method. "Invocation" forms of expressiveness were maintained only for religious and cult practices. These were taken as armament by priests and preachers as forms for the hypnotizing of the will and consciousness of the people, and as forms for their religious stupefaction. However, in primitive thought the "invocation" form of the expression of ideas was still far from any kind of meaningful disorganization of the people and indicated only how much the people believed in the expressive forces and possibilities of ideas.

This property of primitive thought as a whole also pertained to artistic thought. In essence, the expressive characteristics of the thought of ancient people transform all the thought forms in art. The verbal structures of ancient mythology confirm this. These structures are ornamental. They are particularly effective, for they create the specific structure of the signal effect on the spiritual world of the perceivers by such ornamental pressure of philological periods.

A similar type of ornamental pressure of the object represented occurs in Easter images. Thus, for example, in images of animals on the ceiling of the Altamira cavern in Spain, we observe the multiple repetition of drawings of aurochs, caught in various poses, in various foreshortenings and aspects of behavior. These poses and foreshortenings create for the viewers mutually corrected and mutually strengthened versions, i.e., it is the ornamental structure of the various behavioral inflections of the animals which transmit the powerful stimulus of expression for the perception and consciousness of the people. The primitive artist not only attempts to represent animals in his drawings, but through the conveyance of expression and habits of the animal he attempts to infuse into the consciousness of the persons in the environment the stimuli which will organize their will and behavior. Therefore the sense of all Easter and cavern images is first of all authoritatively organizational. It is this particular characteristic which has become the esthetic expressive strength without which art cannot manage. At the time when art appears this organizational force was the main point. It attracts and startles us in the art of primitive artists.

The same thing also applies to the dances of primitive peoples. The rhythms themselves of the dance become a disturbing force, just as did the rhythmic motifs of ornament or the ornamental pressures of the verbal periods. In this sense Professor I. S. monov is absolutely correct when he writes: "A group of primitive hunters executes a ritual dance. From time to time the warriors attack with spears and steeds the figure of a mammoth, drawn on the wall (such drawings with traces of blows have been found frequently by archeologists). Do the dance participants obtain additional information on how best to hunt the mammoth? Apparently they do not. Have they acquired a new experience? Perhaps only the youngest have done so. But after the dance the group which set out on the hunt was not a herd of trembling creatures, ready to run at the first defeat, but a collective of warriors, assured of victory, seized by combat excitement and filled with enthusiasm and strength."

This was accomplished by the force of the dance rhythm acting in the given case as a signal origin, awakening and organizing the internal energy and will of the primitive hunters. Thus the artistic mastery of antiquity reveals to us in its own way initial esthetic values particularly in the structure-signal significance of its images.

Again during primitive times, during the era of the birth of art itself, an esthetically expressive force appeared outside of which there can be no concept of subsequent artistic mastery.

The force of this penetrates each cell of works of art and of the artistic fiber, the entire meaningful content of images, and the entire living significance of art. The meaning of this force is not only that it transmits the image of objects and phenomena, but that it facilitates the very structure of expressiveness to enter into the state of the psychic image in the spiritual world of the observers and awakes in them a definite mood.

This organizational-expressive side of artistic thought and artistic mastery evolved during the entire history of the development of art. It even became to a certain extent a criterion of esthetic value itself for artistic works. This is why each genuine work of art serves not only as a means for the recreation of reality in artistic images, not only as a means for a figurative concept of reality, but also as a conductor of basic organizational forces for human affirmation in the world. The artist becomes an artist in order to see and to reproduce his figurative concept of the world not only as cognitive value, but also that the structure of the images will be, for the reader, viewer or listener, a mood-directing foundation signal. The feeling and consciousness of the observers must produce and burn with the same passionate fire which the artists themselves see in their works and images.

The organizational foundation also tunes simultaneously the internal structure of the expressive means of the artistic work itself and, having been transformed into a state of an ideal psychic image, attunes also our entire spiritual world--perception, consciousness and will. Therefore the same meaning of esthetic organization is a double one in that on the one hand it pertains to the internal structure of artistic expressive means, and on the other hand it is a characteristic organizational foundation for the spiritual world of the observers.

Of course, the main mobilizational method in works of art has always been the "reflection of life in the forms of life itself." Reflected in works of art, living facts convince by their directness.

But there is also in art the mobilization of human will, perception and consciousness so that an esthetic organizational foundation occurs. Here it is not facts which are mobilized, but the very structural-organizational force which transforms artistic materials into esthetically active values. This not only facilitates the image-cognitive function of works of art and the better mastery of ideas and images, but also fulfills the esthetically stimulating function of inciting and actively producing our perception.

Even an artistic project, while still only in the head of the artist in the form of ideal psychic images, is not created with a simple, flowing, figurative concept. Both in an artistic plan and in its embodiment in an already completed work of art, the painter, writer, and sculpter are able to organize the psychological and high-principled value of the images so that they not only transmit the typical characteristics of the individual, but also add at the same time that force, which acts, in accordance with Balzac's expression "With the movement of life", and is capable of actively affecting the perception and consciousness of the people. Communicated to the readers, viewers or listeners, this force is transformed for them into a psychologically active foundation which correspondingly organizes both the very structure of the senses and the consciousness.

In other words, the artist not only thinks figuratively, but he is able to organize the internal structure itself of the images so that it becomes a characteristic factor capable of appropriately arranging the feelings and consciousness of the viewers, readers or listeners. In this connection such organization in structure of the images is certainly not any kind of element of form and is not a compositional formulation, but is an inseparable property of the content itself, of the transmission itself of the meaningful thought in artistic works.

Such is the structure-organizational function of works of art.

In his short story "The Blue Cup", A. Gaydar remarkably reveals the novelty in a vision of the world. A small girl finds out from her father many new things concerning the environment and objects of reality. With direct inquisitiveness she obtains her first-formed view of the world. This is the plot of the story. But the architectonics of the narrative structure of the story attempts to find its response in the soul of the reader. It has the esthetic purpose of awakening in the reader such stimuli for a fresh, transparently new and crystal clear perception of the world that all colors, all sounds and all objects will be unusually bright, prominent, outstanding and as exciting as a "first-formed" interest. Briefly, the architectonics itself of the structure of a story, merging with the development of the plot, becomes a signal structure which is capable of optimum development of the perception and consciousness of the reader for a "first-formed" sensation of the world.

We shall now take an example from the comparatively recent past. The story of Karamzin, "Poor Liza" is sentimental not only in idea but also in plot. With all of its stylistic structure, even more so perhaps in the plot, the story is directed toward "cheerful sensitiveness," which destroys any aspect of firmness on the part of the reader's perception of the world. In this sense in Karamzin's story the idea, the plot and the stylistic structure are "suspended" from the tuning fork of sentimentality.

The harmonious foundation of the Rublev "Trinity" penetrates the soul of the viewer in a striking and winning manner. This permits a significantly softer perception of the human images and the images of the object world, and the capturing of their rhythmic bond. Therefore in the "Trinity" of Rublev, as correctly noted by V. N. Lazarev, the investigator of ancient Russian painting, "There is something calling and tender, which inclines one to extended contemplation. The lines themselves have something which is so melodious and so tuneful. They are warmed by deep feeling and for a long time after contemplation, the viewers of 'Trinity' sense in themselves the echo of these remarkable harmonious lines."

In the remarkable description by Gogol' of the Ukrainian night, the very structure of the narrative, the selection of stylistic methods and finally, the rhythmic-intonational constructure of the periods represent a structure which makes the entire description inspire rhythmic prose; in striking our perception the narrative of Gogol' creates a romantically exaulted and emotion-arousing poetic glow in our senses.

In comparison with literature, painting and sculpture, decorative art, for example, contains practically no image-cognitive significance, but nevertheless we cannot deny its esthetic value. This value is concentrated in this form in the sense that it more or less directly clarifies the force of the esthetic organizational foundation in a more "stripped" form than in such image-cognitive forms of art as literature, painting or sculpture, in which this force to a certain degree is veiled by the cognitive sense of the images.

Beginning at the end of the XVIII Century, when the philosophical systems of German classical idealism were created, which were devoted to the development of the dialectic of human consciousness, art in these systems was examined only from its image-cognitive aspect. Esthetically the organizational aspect of art remained in oblivion. This tradition of the concept of art was maintained in one way or another up to the present time.

However in speaking of artistic value we must not define it as cognitive force only. It is necessary to understand it as an esthetically organizing force which is capable of esthetically orienting our entire spiritual world.

However, esthetically the organizational force may remain in various isomorphic states. Therefore in works of such cognitive forms of art as literature, painting and sculpture, esthetically the organizational force does not act by itself, but in the isomorphic states of the images themselves and of the artistic fiber of the works, while at the same time still remaining a force which is capable of esthetically orienting the spiritual world of the observers.

It happens that a work apparently written in accordance with the rules, with observance of the truth of life and with regard for individual and characteristic relationships, is still perceived by us as non-artistic. We sav that this work does not impress or inflame us esthetically, that it is esthetically weak, and that it does not bear a single spark of artistic excitement.

In such cases traditional poetics usually speaks of the artistic weakness of such works. But traditional poetics cannot answer and does not answer the question as to why this is true and where in works of art we may find that esthetically active "zest" which characteristically gives a work of art its esthetic value.

While asserting the signal-like nature of the organizational effects of esthetic and artistic values, by the same token we may in a certain way explain this "zest" of esthetic action.

In fact, as has been made clear from cybernetics, only a signal which corresponds to a certain system is capable of setting it in motion, while merging in an isomorphic state with the structure of this system.

Not yielding to study from the point of view of traditional poetics and thus remaining hidden, the force of esthetic effects becomes completely explainable and carries nothing irrational if it is looked upon from the point of view of the signal property.

In revealing the signal basis of the effect of the esthetic foundation and of esthetic and artistic values, we see that a study of information theory helps to clarify much in the esthetic forces of artistic value.

THE AUTHOR, THE CONSUMER AND OTHERS

Doctor M. Kempisty (Poland)

We wish to present here certain problems which touch upon works of art and for this purpose we shall employ the concepts of cybernetics. This is a rather thankless task, since cybernetic investigations usually result in a calculation of the course of the process investigated. Among the many conditions required to conduct such calculations, there is an indispensable condition; this is the capability of measuring the objects investigated. But if we speak about art, we are dealing with objects for which science has found neither measurement units nor measurement devices.

We shall speak here about esthetic experience, treating it as an internal state of man (internal from the point of view of psychology and physiology), which exerts an influence on a subsequent internal state. Thus *esthetic experience* appears in our discussions as so-called self-locking links and whenever required will be examined only qualitatively, with no quantitative approach involved. However, limitation of the discussions by the qualitative aspect is a general and thus far an unremovable shortcoming.

First of all it is necessary to assume that the reader of this article has mastered known concepts in the field of cybernetics, particularly in the theory of relatively isolated systems. Speaking concretely, it is assumed that the reader knows:

About the relatively isolated system (or more properly, concerning a system which is developing and which is reliable), and he has, therefore, an understanding of *input* and *that a stimulus* is the state at the input and the *reaction* is the state at the output;

About local determinism, i.e., he understands that in a growing system each reaction is determined by stimuli which act simultaneously with the reaction or which have occurred in the past;

That the system acts on other systems by means of *communications*, and on itself by means of *feedback;*

About *reinforcement* (i.e., the supplying of mass or energy) and has an understanding of *information* (as opposed to the concept "supply").

Thus the knowledge required from the reader is not great and it is not difficult to master it.

By employing the concepts cited above, we may attempt to construct a model of the origin of a work of art (Figure 1). Such a model consists of two systems:

WA--*work of art*--created by the artist with the aim of stimulating esthetic experience in other people;

A--*author*--individual person or a group of people who created the work of art.

Both systems are defined relatively--one depending on the other, since mutual connections exist between them. These connections are as follows: the informational connection A-WA (from the A system *to the WA system)*, the reinforcement connection A-WA and the informational connection WA-A.

We may consider the A system to be each man, regardless of his profession, who creates a work of art (a picture or a musical composition). The A system is also a group of people (the author of song lyrics and the composer of the melody, or several architects from one organization), who create works of art together.

The WA system is any work of art created by author A with the aim of evoking positive esthetic experiences (we say positive here because negative ones also are possible). Sometimes the author thinks that his work of art is epochal, and sometimes he only wants to please the consumers, or even only one consumer, for example, a beloved woman or a wealthy patron of art.

We shall now pass to a detailed examination of the inputs and outputs available in our model, and we shall begin with the A system.

Personal reinforcement--this is required so that the author can create, for example, energy reinforcement (nourishment and breathing) and energy isolation (clothing, shelter).

Memory--this is the entire history of the author including all of the information which he obtained before he began to create his work of art. (Thus we understand the term "memory" more broadly than previously accepted, and more broadly than the term is accepted in psychology). This so-called memory includes inherited features, knowledge obtained during studies, personal experiences, esthetic experience, etc. This encompasses millions of bits of information, collected in the author's brain in specific structures and comprising his individuality, talent, etc.

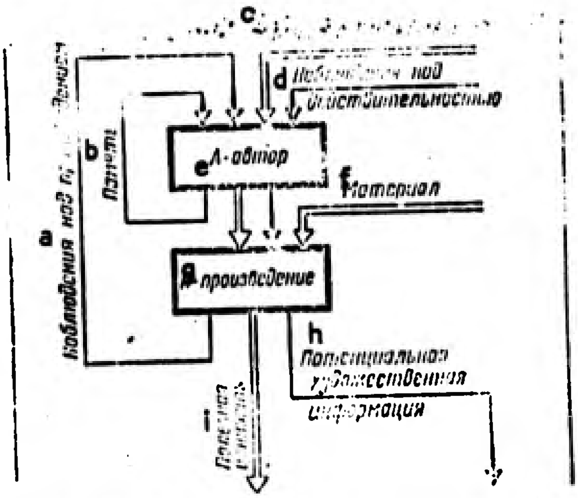


Figure 1. Key: a, Observation of the work of art; b, Memory; c, Personal reinforcement; d, Observation of reality; e, A-author; f, Material; g, WA-work of art; h, Potential artistic information; i, Useful value.

Observations of reality are accomplished by the author during the period of the creation of his work of art. The role of this information is usually insignificant in comparison with the role of information held in the memory. In certain types of art this input is deserving of attention, for example, in attempts to understand different trends in painting, by carefully determining the type of transformation to which a selected fragment of reality has been subjected.

Observations of the work of art are accomplished by the author many times during the process of his creation. Each change in the work of art accomplished by the author (both connections A-WA) evoke a new evaluation of the work of art as a whole (informational connection WA-A), which in turn influences subsequent changes which are made in the work of art produced (again through the informational connection A-WA and the reinforcing connection A-WA). Thus we are dealing here with *feedback*.

Within the A system there occurs a transformation of stimuli, obtained at the inputs enumerated above, in specific creative acts (informational connection A-WA), as well as those obtained from unavoidable acts in this connection (for example, shaking of the hands during painting, drawing, etc.), although these are not essential for art discussions, the actions have the character of reinforcement (reinforcing connection A-WA).

In order to create a work of art the author requires not only "working force" (reinforcement!) and "spirit" (information!), but also *materials* (paper, pencils, a typewriter, marble, solvent, a root of fantastic shape, etc.)

Two outputs come from the WA system, aside from the WA-A connection already mentioned.

Useful value in a work of art is seldom encountered. This would encompass, for example, a table, covered with a beautiful mosiac, on which we place coffee and pastry. This quality is also possessed by a volume of verses when we use it to light a fire or for an autographed present.

Potential artistic information serves to excite esthetic impressions for a potential consumer. This information is always possessed by the *material aspect* (letters, sheet music, colored spots, and also their mutual arrangement), which sooner or later we will be able to formalize, i.e., perceive as a unique mathematical record.

During the past ten years a great deal of investigation has been carried out in the entire world on this topic. It is impossible to examine this work here even in approximate form, since in this case it would be necessary to become acquainted with the basic concepts of information theory and probability calculations, as well as to cite several numerical examples. We shall point out that only as a result of these investigations such achievements have appeared as the ability of an electronic machine to distinguish the text of one author from the text of other authors or the ability to compose a short musical composition of a specific type.

In addition to the material aspects, artistic information also contains an *emotional aspect*, which evokes esthetic experience in the consumer. Perhaps in the future cybernetic investigations in the field of artistic information will permit us to clarify the types of elementary signal structures (for example, letters, sounds) which evoke in the consumer the maximum emotional effect.

With this we shall terminate our examination of the model of the origin of a work of art; the work has been created, exists and will exist until such time as it is destroyed. In subsequent discussions we shall devote our interest only to potential artistic information which the consumer may receive (although he is not obligated to do so).

We shall begin our discussions touching upon the perception of a work of art with the characteristics of the *O-consumer* system (Figure 2), with an examination of its inputs:

Artistic information through the WA-O connection: the consumer looks, reads or listens to the work of art.

The *memory* of the consumer in principle is the same as the memory of the author. However, experience in the perception of a given field of art, as well as associations with the circumstance of perception of similar works of art deserve special attention here.

Personal reinforcement merges from the same factors which the author has. These must be considered here, since impressions will certainly be somewhat different for a hungry or cold consumer. We shall assume that the consumer who actively breathes the remarkable mountain air is particularly sensitive to beauty.

The influence of the medium--this is mainly an evaluation heard or read by a given consumer of works of art which are close to that which is being perceived at a given moment. The influence of this input is usually underestimated.

Stimuli from all of these four inputs evoke specific reaction in both outputs of the O system. The first of these outputs is *esthetic experience*, which is experienced by the consumer (this output is the self-locking connection in the system), and the second is *conscious opinion of the work of art*. Consumers are sometimes encountered (for example, children) in which identical reactions are found at both outputs.

A work of art furnishes artistic information in a specific *code*. It is not always that the code permits the consumer to perceive the work of art directly (as in the diagram in Figure 2). In many works of art a translation from one code to another is required. This translation is accomplished in the T-*translator* system (Figure 3). For example, a pianist may be a translator for a musical composition; he translates the composition from the code of notes to a specific audio code. The quality of the translation is then influenced by the state of the piano (reinforcing input), and by the art and talent ("memory") of a given translator.

Poetic works of art may be perceived directly (if the consumer reads them for himself), but may also be subjected to transformation in the translator system. The translator may be a reader who transforms the written word into the vocal word. The translator may also be an ordinary translator who translates poetry from one language to another. A situation may also arise when poetry, translated, let us say, from Russian into Polish, will then be read aloud; then we are dealing with two translators T_1 and T_2 and with connections WA-T_1 in the α code, T_1-T_2 in the β code and T_2-O in the γ code. Each translator, if he is a specialist (or a group of specialists), correctly translates the material aspect of the work of art. But whether he translates the emotional side, whether he imparts the author's conception, enriching it or "cutting" it in his translations--this depends on his *memory* (in the meaning of the word accepted here) or on his capabilities, intelligence and talent.

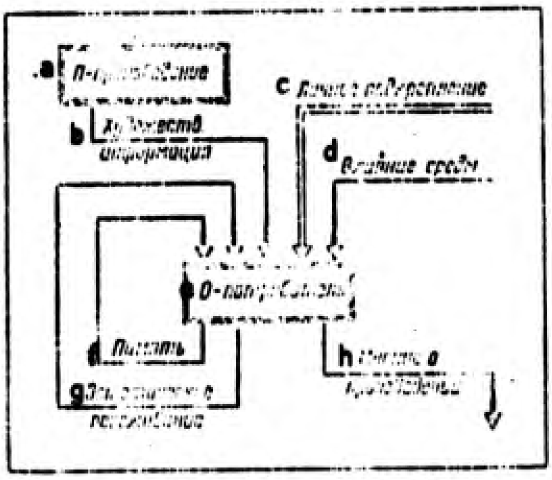


Figure 2. Key: a, WA-work of art; b, Artistic information; c, Personal reinforcement; d, Influence of the medium; e, O-consumer; f, Memory; g, Esthetic experience; h, Opinion concerning the work of art.

In all of the preceding discussions we had in mind only one consumer, while an artistic product is usually a social activity and almost every author wants his work of art to be perceived by many people. So that it may be seen by thousands of consumers, the condition of *reproduction* is required (although it may be insufficient).

Reproduction is the role of the system called the C-copier system (Figure 4).

Such a system may be typography, which issues thousands of copies; a museum, accessible to crowds of viewers; a radio, which transmits recorded music; a motion picture theater, which presents (many times or even only once) a given program, or television, which presents film made previously.

It is assumed that artistic information at the input of the C system is identical with artistic information at all of its outputs, although this assumption is a simplified one. For the reproduction of this information we require, in addition to characteristic stimuli for reinforced inputs (see Figure 4), a decision to reproduce it, made by a competent element. We call this element the *P-popularizer* system. This is usually a patron of art, the owner of a press, an editer-in-chief, the board of an appropriate ministry, or the director of a museum.

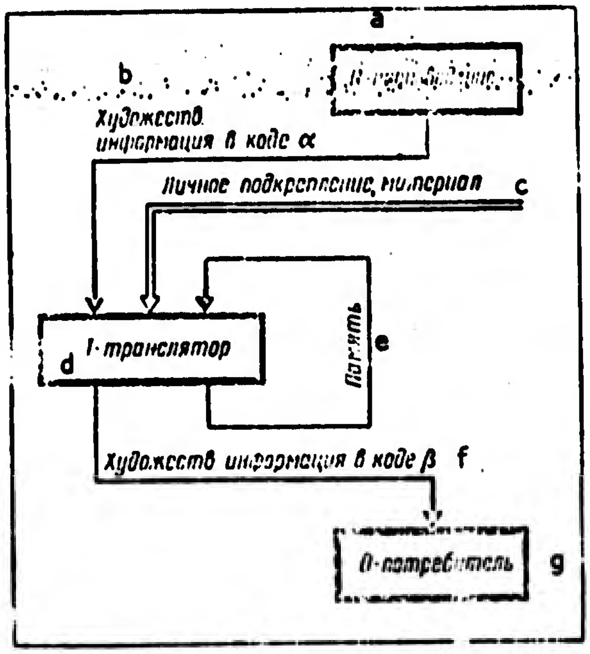


Figure 3. Key: a, WA work of art; b, Artistic information in the α code; c, Personal reinforcement, material; d, I translator; e, Memory; f, Artistic information in the β code; g, O-consumer.

Figure 5 shows an overall diagram of the popularizer. The following stimuli influence the output reaction--"the decision to reproduce":

Artistic information;

Economic information, which furnishes material for an evaluation of the profitability of reproduction (by copier K) or of secondary usefulness of reproduction;

Political information, which furnishes material for an evaluation of whether reproduction of a given work of art is profitable from the point of view of the long-term policy of the popularizer (whether the consequences will be useful or harmful for a given enterprise, social group, etc.);

The opinion of experts (for example, a reading of criticism of previous works of art of a given author);

Personal views of the popularizer.

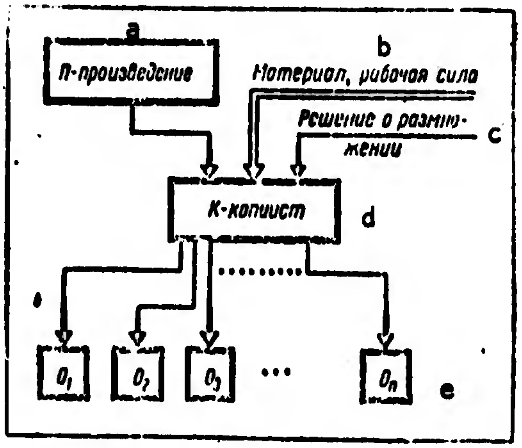


Figure 4. Key: a, WA work of art; b, Material, working force; c, Decision concerning reproduction; d, K-copier; e, O_p.

Thus in Figure 5 we have five inputs which influence the decisions taken concerning reproduction. For each given popularizer the stimuli at individual inputs act with different force: for example, sometimes the popularizer's admiration dominates, while sometimes economic information is predominant. However, the decision of the popularizer is always influenced in a certain measure by each of these five stimuli, so that to ascribe an exceptional influence to the stimulus of "artistic information" means closing ones eyes to reality.

The reactions of the reinforced popularizer output must provide the copier with the capability of accomplishing a decision concerning reproduction. P systems exist which never give reactions at the reinforced output which are not equal to zero (for example, a censor).

The three systems mentioned--the translator, copier and popularizer--are not obligated in any way to be individual organizational units. It frequently happens that the popularizer is the director of an institution, and his co-workers fulfill the multiple transformation of a work of art so that in the final analysis it is reproduced for thousands of consumers.

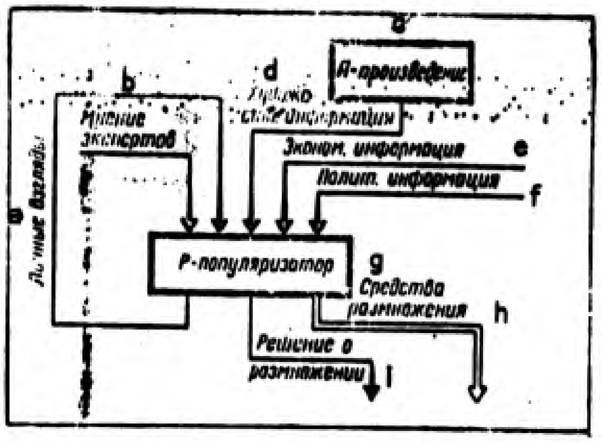


Figure 5. Key: a, Personal views; b, Opinion of experts; c, WA work of art; d, Artistic information; e, Economic information; f, Political information; g, P-popularizer; h, Reproduction methods; i, Decision concerning reproduction.

Let us now examine a model of the social perception of a work of art (Figure 6). This model is extremely simplified in comparison with reality; this appears, by the way, in that we have encountered each type of system only one time. Here the O system is seen three times. The first two of these, the "consumer-layman", designate the broad masses of consumers and the third one is the "consumer-expert", who differs by a special property which may be understood from the drawing.

The drawing shows only those connections which characterize a model of social perception; several of the inputs and outputs which are already familar to us have been omitted for greater clarity in the drawing.

At the very beginning of our discussions we acknowledged one weakness which has a methodological nature; specifically this involved the impossibility of measuring those features of an artistic production which present esthetic interest. But even under these unfavorable conditions the cybernetic point of view apparently proved to have a certain value. Here we wish to present schematically a situation of an artistic work of art within the frameworks of a complex network which has a social nature. If someone should reproach us for the fact that we have not given a standard for a cybernetic approach to esthetics, but rather a textbook for the cybernetically comprehensible sociology of an artistic work, then we can only agree with this reproach.

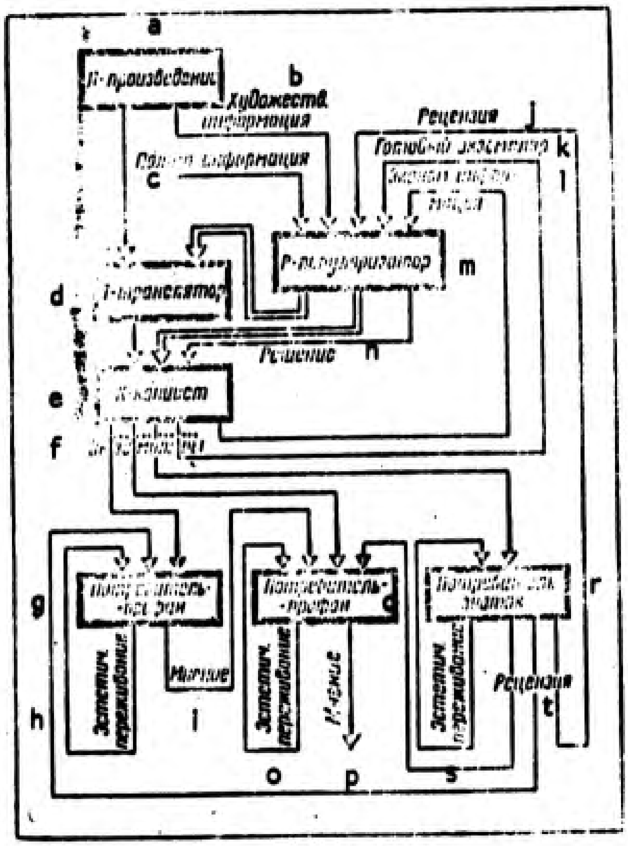


Figure 6. Key: a, WA work of art; b, Artistic information; c, Political information; d, T-translator; e, C-copier; f, Copies; g, Consumer-layman; h, Esthetic experience; i, Opinion; j, Review; k, Prepared copy; l, Economic information; m, P-popularizer; n, Decision; o, Esthetic experience; p, Consumer-layman; q, Opinion; r, Consumer-expert; s, Esthetic experience; t, Review.

The social network consisting of the author, consumer, translator, copier, popularizer, expert and even the consumer-layman, clearly has a schematic nature; it is not reality, but a *model*, i.e., a simplification of reality.

It would be good if the reader, before becoming indignant about the "intolerable diagramming" of these discussions, would remember that in the natural as well as in the social sciences reality is investigated not directly, but by means of the construction of simplified models. Reality is too complex to describe it fully and exactly and to make it accessible for investigation without simplification. The work of the investigator, of his talent, experience and tact is to construct a model sufficiently close to reality (i.e., of sufficient complexity), so that it may be investigated and at the same time sufficiently far from reality (i.e., simplified), so that it has a didactic significance. Only such investigations will have practical value.

In accordance with this consideration it is still difficult to express relatively the values of the model cited above (one of many possible ones) or the expediency of constructing other models on principles set forth here. But nevertheless we have described here the basic problems in the sociology of art, in definite, simple and clear language, the language of common cybernetics, while avoiding traditional unclear terms which are often employed by professional critics of art. We hope that the elimination of unclear terms leads to the disappearance of discussions of various imaginary problems. The formulation of problems touching upon the role of art in society, upon language applied and applicable in other sciences (in economics, in the study of language, and in medicine), i.e., in the language of cybernetics, opens up new possibilities for us. Due to the employment of a common language, these problems will become comparable with those which we encounter in other, quite varied branches of science.

THE LOGIC OF POETRY

Doctor of Physicomathematic Sciences, G. Khil'mi

Each word used in business or scientific language may be employed in poetry. But why do the meanings of the same words, when employed in poetry and in ordinary language, frequently differ from each other? Why in poetry are combinations of words possible which, from the point of view of the logical ordinary language, have no meaning but nevertheless do not seem to us to be an accidental choice of words? Thus, for example, in the stanza written by S. Yesenin:

Now I grow more tame in my ambitions.
Life, were you dreams and no other thing,
As if I galloped by on a pink stallion
Through the echo-filled mornings of Spring?

We do not perceive the two last lines as a communication to the effect that on a Spring morning someone galloped on a rose-colored horse.

Just as the words of A. Blok

And the ill will of the director
Carried the wind through the harps

Of course this does not indicate that as a result of volitional impulse on the part of an embittered director in a concert hall, flows of air arose which blew on the harps.

But if the "logic" of poetic language differs from the logic of ordinary language and the language of science and thus permits us to broaden the meaning of the words employed, then naturally the desire arises to understand this phenomenon and to answer what appears to be at first sight a very simple question: what is the essence of these differences? Searches for the answer to this question lead us to the borders of psychology and theory of knowledge.

Sensations generate in man's consciousness representations of objects and events of the external world, which represent for him sources of information concerning this world. These images provide man not only with information; in addition, they evoke specific emotions and become the source of his internal experiences. Events of personal or social life also evoke definite emotions: joy or grief, quiet certainty, hope or alarm, and sometimes a feeling of fear.

Of course not all information is accompanied by emotions. For example, practical reference information, which orients us in one respect or another, including tables of mathematical or physical values, train schedules, road maps, rules for the servicing of technical devices, traffic rules for city transport, etc., ordinarily evoke no emotions.

However in the overwhelming majority of cases involving the perception of elements of reality, and also their images on photographs, motion picture film, and their reproduction in the memory or their verbal description not only furnish us with information concerning these elements, but simultaneously cause definite emotions. Any kind of essential information is emotionally colored.

Thus, *information and emotions are combined in the consciousness of man.* Emotional accompaniment resounds within man during his entire life.

Information which enters the consciousness of man in connection with the perception of objects in the external world and in connection with the perception of events surrounding his life reflects the objective properties of reality. The ability to experience emotions is an objective property of man but it is an internal property of his psyche, which characterizes his intellect, rather than the external world. Emotions are one form of the regulation of human consciousness, which reflects its attitudes toward objects and events of the environment. Therefore emotions may force man to act, to desire something, or to strive purposefully for something.

Notwithstanding the fact that the ability to perceive information and the ability to experience emotions represent phenomena of various aspects of our consciousness, *a regular conformity exists between the content of specific information and the nature of emotions which is associated with this information in our consciousness.*

Perceptions or recollections which contain similar information evoke similar emotions. On the other hand, perceptions or recollections which are quite diverse with respect to information content generates different emotions. Everyone knows from personal experience how different the emotions are which are caused by a picture of a stormy sea and that of a starry sky on a dark August night. The impressions from a violent waterfall and from the calm flow of a broad, full river are not comparable. No one will identify or confuse emotions caused with information concerning joyous events and those associated with grief. Similar examples may be cited as required.

The conformity which exists in the consciousness of man between emotions and information explains why the emotions may become for man carriers or sources of information.

In fact, let certain information A be associated with emotion B. Let us assume that in some way or another we may excite in man emotion B, while not transmitting information A to him. If the individual who perceives this possesses a suitable level of emotional culture, he will accomplish an association of emotion B with information A in his consciousness, and thus a concept of its content will arise. Of course this concept will unavoidably be generalized and somewhat indefinite, but nevertheless it will be correct.

This sketch may appear to be abstract and far-fetched. However, this is not true. A factual confirmation of this sketch is the transmission of musical information, for example, a symphonic work, not accompanied by song or by choreography (which in themselves could be sources of information). It is obvious that the direct transfer of information does not occur in symphonic music. But it is capable of exciting in the consciousness of the listener emotions which are associated with certain information. Thus in symphonic music the transmission of information occurs through emotions, i.e., secondarily.

It is indisputable that information which is transmitted by a symphonic work is not simple and each listener will impart to it a subjective shading. But this is not arbitrary. The brilliant description of the repulsive automatism of Hitler's war machine, expressed musically by Shostakovich in his Seventh Symphony will not be accepted by anyone either as a lyrical song or as the rustle of leaves during a hushed autumn night, or as the thunder of the breakers on rocky shores. Although the listener does not receive specifically expressed sociological information, the condemnation of war, expressed musically, possesses tremendous conviction. If we permit ourselves to employ cybernetic terminology, then we may say that the information contained in the symphonic work, indirectly transmitted through emotions, possesses significant entropy; however, this is not chaos, and it is not noise deprived of meaning. In a meaningful sense it is intensively generalized information which leaves broad possibilities for concrete aspects, but specifically in accordance with its emotional coloring.

Each man maintains in his memory in the form of generalized concepts a store of emotionally colored information. He has acquired through multiple repetition the experiences of ordinary phenomena of life and the perception of nature which surrounds man. Pictures of the woods, the stepps, the sea, the mountains and individual phenomena of nature--dawn, a storm, a starry or rainy night, separate objects--stars, clouds, grasses, woods, birds and animals--all of these form concepts in human consciousness, which contain emotionally colored information. Very many ordinary concepts, which contain emotionally colored information, are acquired by man through his personal living experience, by observation of the life of the people around him, by his relationships with these people and also under the influence of social life.

Emotionally colored information, accumulated in the experience of ordinary existence and available to each individual, is fixed in the consciousness of the individual in the form of overall concepts and is arbitrarily called *primary, emotionally colored information.* In perceiving or processing in our consciousness primary emotionally colored information, often we do not note the emotions associated with it; they are the usual ones for each of us and show practically no difference from similar emotions in other people. Of course, during different historical epochs people commanded a different store of primary emotionally colored information. This occurred for many reasons, first of all due to changes in the human real environment, which were frequently caused by man himself. Thus, for example, in our time it would be difficult to find a man for which the distant whistle of a steam locomotive at night would not be a source of primary emotionally colored information. However, prior to the invention of the steam locomotive and the construction of a comparatively wide network of railroads, such emotionally colored information did not exist. The material and spiritual progress of man and the complexity of social life gradually increases the store of primary emotionally colored information. At the present time this process occurs with particular intensity.

In poetry we employ the capacity of words to transmit information to man. The source of information in equal measure is represented by words pronounced by others and words which we pronounce ourselves--either aloud or silently, for example, during minutes of thinking, recollection or during the reading of books.

Any kind of poem or separate lines which make up a relatively autonomous part of a poem must include subject information which permits the reader to find out what the poem is about and the logical content of the verse. Arbitrarily we call this information the "direct" verse information. However, the direct transmission of subject information and its logical meaning is not the task and aim of poetry. "Direct" information is only the skeleton of a verse rather than its living tissue.

In poetry any kind of information is examined from the point of view of its emotional coloring, and the task of poetry consists of decisively passing beyond the limits of ordinary primary emotions. Therefore, a reflex, self-generating emotional coloring of information cannot form the richness of poetry. The primary reflex coloring of information by the emotions is employed in poetry only as initial material, similar to the way in which the selection of colors on the palette of an artist represents the initial material for the creation of a picture.

The basic principle for the solution of the difficult problems in poetry is included in the following. To "direct" information, which possesses an inherent primary key, we add supplementary information, which in the point of view of meaningful logic may and may not be connected with the "direct" information, but which, with its emotional sound, increases or intensifies the emotional coloring of the "direct" information and even gives it a new shading. This supplementary information, employed for the emotional tinting of the "direct" information, is appropriately called "image" information. It is associated with "direct" information not by objective logic, but by "the logic of emotions." It is for this reason that combinations of words, which have no meaning from the point of view of ordinary language, become understandable in poetry.

We shall attempt a direct analysis of some lines of poetry in order to clarify this abstract in rather difficult concept.

Let us return to the stanza of Yesenin which we quoted at the beginning of this article.

Now I grow more tame in my ambitions.
Life, where you dream and no other thing?

contain information of a growing miserliness in ambitions and that the part of the poet's life which has passed seems to be a dream.

Let us take the next two lines, leaving out, however, the first two words; they read:

...I galloped by on a pink stallion
Through the echo-filled mornings of Spring.

In the form just quoted these lines contain information that the author galloped on a pink stallion during an echo-filled morning in Spring, i.e., the information content has no meaningful connection with information contained in the first two lines. However, the omitted words "As if" in the third line completely eliminate any bewilderment. It appears that Yesenin in the last two lines is not at all informing the reader that he galloped on a pink stallion; these lines, in conjunction with the first two and with the help of the words "As if" mean that the past life of the poet seems like a dream, filled with the same emotions which might arise if he would gallop on a pink stallion in early Spring. Therefore, it is not the content of the two last lines, but rather the emotions stimulated by them which are joined to the first two lines of the stanza. In other words, the last two lines serve as an emotional tint for the first two. It is not the association of content, but rather the associated created by the logic of emotions which makes the stanza examined purposeful and poetic to a high degree. It is clear that the first two lines contain basically "direct" information while the last two contain only "image" information; the emotional ring of all four lines merges in a single poetic accord.

In turning to the first stanza of another poem by Yesenin:

I've decided, now, to abandon
My home fields which I no more shall see.
And the poplars will no longer rustle
Their winged foilage above over me.

Without difficulty we detect that the first two lines contain "direct" information to the effect that the poet has decided irrevocably to abandon his homeland and that the following two lines contain only "image" information which speak of the emotional color of the decision taken, and of the secret feeling of doubt.

It is interesting to note that the last two lines, taken alone, express emotions of doubt, without, however, specifying the cause, which remains to a certain degree indefinite. In actual fact, these lines could also pertain, for example, to dried or cut trees. However, when we combine these lines with the first two, the uncertainty disappears: the poplars will no longer rustle in the author's verses as a result of his final departure from his homeland. We are again convinced of the indivisibility of "direct" and "image" information in verse. The collision or interaction of these two types of information generates something new, which is contained neither in the "direct", or in the "image" information, which, when taken in isolation are examined independently of each other.

We have cited relatively simple examples in which the "direct" and "image" information are very clearly separated and it is easy to point out the lines in which each type of information is contained. Frequently, however, both types of information are interwoven and it becomes impossible to separate them so simply.

It is difficult and obviously not necessary to give an exhaustive description of methods of the construction of verse which permit the reader to distinguish "direct" verse information from "image" information, which participates in verse not with its literal sense, but with emotions, generated in the consciousness of the reader and coloring "direct" information. In any case one point is clear: verses must be written so that this aspect of the question does not generate any insurmountable difficulties for the reader.

"Direct" and "image" information must be present in each verse. However, the relative volumes of these types of information may be quite different, and in this respect no standards can exist. Sometimes "direct" information is only given in the form of a weak allusion, in one or two lines, and the entire remaining part of the poem is "image" information, which evokes the associations required to color the "direct" information. Such poems may exert on the reader a strong influence which resembles the influence which we experience from musical works. As a successful example of this, we may point to the poem of Svetlana Kuznetsova.

We grow from our childhood
With the blue land in our hearts.
From where comes the river Vitim?
From blue reflections?
From where comes the river Vitim?
From thought, perhaps?
Do you want to fly away
To blow one hundred fires about?
Do you just want to fret and find no refuge anywhere...
From where comes the river Vitim?
Does it come from childhood?

Only the first lines, which by the way are not free from "image" information (blue land), contain a hint of "direct" information concerning the ties to our homeland which return with the passage of time. The last line adds to this information referring us to childhood. The remaining lines create an emotional accompaniment associated with this information. They represent poetic music. We shall become convinced of this if we read the poem again but this time omitting the first two and the last lines.

Thus the image concept is the spirit of poetry. The musicality of speech, i.e., its rhythm, its terminal and internal rhymes, assonances and other forms of the organization of a poetic line may substantially reinforce the emotional effect of the images, but in themselves they are insufficient for this effect. In other words, the musicality of verse is not the source of its effect, but is an amplifier which becomes useless if there is nothing to amplify. There is no poetry without images.

This may be proved by the experimental method.

For this purpose it is sufficient to write a poem in which rhymic demands are fulfilled, which has rhyme, but no images, and we shall become convinced immediately that such a poem cannot be termed a poetic work.

In former times the verses of Ye. Sokolova and G. Semenov, "At the Pioneer's Campfire", appeared in print:

The beetle propagates thrice a year,
His relatives grow and grow,
And then at the appointed time
The female lays up to eight hundred eggs.
In appearance the beetle is small and slow,
And he is only a centimeter long,
He has yellow stripes on his wings
These are ten--a basic sign, etc.--

--and represents such an example. The text quoted possesses the formal characteristics of verse. However the lack of images completely eliminates any emotional effect which would intensify the information. We are dealing only with information extracted from a text book of entomology; here the verse-resembling delivery of this information does not enrich us and even under the best conditions only helps us to remember the facts.

On the other hand, free verse, without rhythm and free of rhymic rigidity, but written in the language of images may be a genuine poetic work. As an example we cite the poem of the Estonian poet Ellen Niyt in the authorized translation by Yunny Morits:

Time has wings, my beloved,
The days fly like birds before the eyes.
Autumn has come,
A convoy of cranes shouts farewell,
In the sky.
The birch drops
Its autumn leaves
And the stars fall at night
From heavenly branches.
Come quickly! We shall gather
All that summer has left.
We shall taste sweet wisdom of the fruit
And shall save until Spring
The seeds.
And I would like several leaves
To remain in memory
Of this autumn.

Poetry originated naturally as a result of the specific demands of human intellect. The analysis given above shows that poetry, based on primary relationships between information and emotions, is an art which permits the meaningful creation of new associations between emotions and information, transmitted with the aid of words.

The question naturally arises: why is this necessary and what human needs does it satisfy?

This question may be answered in the following manner. Information which appears during our perception of the external world or which is contained in some thought, and the emotional accompaniment of this information represents separate sides of a complete whole. Of course, emotions which express our relationships to objects and events of the external world are generated within us and in this sense they are subjective. But at the same time they are involuntary and represent subjective experiences which are caused by the objective properties of external objects and events.

The emotional accompaniment is required for the transmission of those shades of information which cannot be transmitted by purely logical means. The emotional coloring of information intensifies its perception, makes its perception alive, permits us to sense our relationship to it, and therefore to develop a responsive reaction. Information which is deprived of emotional coloring is dead. By means of combining information with emotions in human consciousness we accomplish a meaningful synthesis of external objective action with internal subjective sensation for a possible or required response to this action. In listening to verses or music, in examining a picture or sculptures, in being present during the development of a choreographic effect, etc., we experience this and evaluate the works of art to the extent that the emotions and experiences reflected in them become our inherent internal experiences.

It is difficult to give an exhaustive list and a classification of specific problems, solved through the use of poetry and other arts. However, individual important cases must be noted.

Not every man can write verse or compose music, but in life every man has minutes which are deserving of representation in poetry or in music. Under these conditions man needs poetry which is capable of reproducing in him something close to what he has experienced and which comprises the internal value of his emotional biography. Thus, with the aid of poetry man can experience that which he has been forced to live through, but which is worthy of experiencing. Not only an accumulation of information but also an accumulation of emotional experiences improves the intellect of man and makes him stronger. Thus some of the significance of the huge emotional stock contained in poetry, music and other arts becomes clear.

The value of poetry as a supplemental means for the expression of the ideology of social movements or of large-scale historical events is very great. It is not accidental that the revolutionaries of the past were drawn to poetry and, while not professional poets, wrote verses. As brilliant examples we may point to Nikolay Morozov and Vera Finger, who were authors of verses which expressed well the mood of the revolutionaries of their time.

If we are speaking of the place of poetry during the days of large-scale and difficult historical events, then we must mention the huge role which poetry played in 1941-1945, when it helped us to formulate our attitude toward events of the war and to reflect this attitude. During those years Soviet poetry inspired the warriors on the military fronts and helped the Soviet people, under difficult war conditions, not only to preserve human dignity, but also to rise to the occasion morally. This absolutely clear fact requires no particular proof, since it is sufficient to remember the well known war-time verses of Simonov, Berggol'ts, Surkov and many other poets.

Even abstract scientific concepts of philosophical truths are colored in our consciousness by the accompaniment of emotions which are very difficult to describe. Scientific positions and philosophical truths are for us not only objects of understanding, but are also objects of feeling. Very frequently not only the information contained in a scientific or philosophical truth, but also the feelings which we experience in connection with this information, permit us to evaluate the concept and to understand its intensity and significance.

Familiarity with Darwin's theory of natural selection and struggle for existence specifically evokes sensations of the organic world as a stormy, suffering but victorious element.

A study of the theory of celestial mechanics produces a feeling which we may call one of the shadings of a sensation of space.

The harmonious development of the logic of a mathematical concept creates a sensation, a paternal feeling, which may be experienced from the musical compositions of Bach.

"In the scientific sense," wrote Einstein, "an element of poetry is always present. Real music and real science require a uniform thinking process."

Poetry opens amazing possibilities for the expression of feelings which illuminate and intensify an abstract concept. Poetry may not only reproduce these feelings, but may reinforce them while introducing no distortions.

We have seen that the task of poetry consists of the transmission of concepts concerning nature, historical events, social goals, the internal life of man, etc., through the use of information were colored by an emotional accompaniment which furnishes an evaluation of this information or which expresses a specific attitude toward it. Poetry represents a type of literature which is not so much informative as active.

But what should guide the poet in the development of images required for the solution of a specific problem in poetry? Obviously he should be guided by a direct sensation of those regular relationships (in our opinion, non-informational), by virtue of which emotions are associated with information in human consciousness. In other words, the task of writing verse capable of displaying the required emotional action must be solved empirically. In creating a poem the poet verifies its effect on himself and by controlling his inherent perception modifies and edits the poem in the process of its writing. It is therefore impossible to write a poem with no cause for poetic perception.

Thus *direct and feedback links exist between the author and the verse which he has created, as a result of which a poetic work is born.*

The concepts which we have outlined permit us to evaluate correctly the capabilities of cybernetic, or, it is better to say, "machine" poetry.

The machine may create texts in which the rules of rhyming and rhythm are observed. The machine may employ a specified volume of information and a store of figurative expressions introduced into it. The combination of information, images, rhythm and rhyme may be programmed and not arbitrary. In essence this is all or almost all that a cybernetic machine which writes verse can do.

But the main point is that which is required for the writing of genuine works of poetry is inaccessible to the machine, unless this machine is a man.

The machine has no requirement for verse, and it does not perceive its verses. There is no feedback between the machine and the verses which it has created; the machine lacks an intellect which is capable of experiencing the inverse effect of its own creations.

In addition, the machine does not perceive the phenomena and events of the external world which man experiences and which furnish the food for his poetry. The machine does not participate in the events of life in the same sense in which man participates and therefore on the basis of living experience and internal experiences the machine cannot control its poetry by means of the feedback required both for selection and for evaluation of the images utilized in the verse for the emotional coloring of information.

The program given to the machine may limit somewhat the random order of information and images in the text, created by the machine, but this limitation is insufficient for the generation of that "emotional logic" which is meaningful and which is the essence of any poetic work. Of course, individual lines may appear accidently in the machine text which are not lacking in a hint of poetic logic and even possessing poetic logic, but like any random happening this will not be the rule, but the exception--and a rare exception.

Actual examples of machine verses confirm our thoughts.

Here is an example of a poem created by the RCA-301 machine, which was taught to write blank verse:

As the dream sailed above the shattered hopes,
Space trickled painfully above a shattered love,
Your light was slowly banished from the hidden people
And the heavens did not sleep.

And here is another composition from the same machine:

All girls sob like slow snows.
Near a couch, that girl won't weep.
Rains are silly lovers, but I am not shy.
Stumble, moan, go, this girl might sail on the desk.
No foppish, deaf, cool kisses are very humid.
This girl is dumb and soft.

The reactions of readers to these lines are interesting. Although they do not create a great impression, nevertheless they are sometimes perceived as poetic works of an average level, although, of course, not completely understandable. I attempted to clarify the reason for this attitude. It turned out that this is explained by a certain uncertainty on the part of the reader, which, no matter how strange it appears, was brought about by the impudence of mediocre and slovenly poets who juggle images and who are inclined to amaze others with an incomprehensible and imaginary intensity, as thought not accessible to all. Many readers, not understanding such authors, take this upon themselves and assume that they do not possess the required level of poetic culture and have not reached an understanding of the more complex forms of poetry.

The excessively frequent penetration of the press by verse written on the level of machine poetry facilitates the propagation of this unjust and depressing concept and hinders the readers' correct evaluation of machine poetry and its capabilities. The reader feels that it is difficult for machine poetry to attain the level of genuine, human poetry. But in this connection he often forgets that verses written by man are not obliged to surpass the level of machine poetry. Therefore, having noted the similarity of machine poetry with certain verses of a certain poet, the reader is inclined to think that in this case the machine has succeeded in approaching the level of human poetry, rather than feeling that the poet has descended to the level of machine poetry.

But there is one area of emotional experiences in which it is impossible to deceive anyone--this is the feeling of love. Therefore, if we charge the machine with writing not a poem, but rather a declaration of love, then immediately we can clearly detect the level of machine lyrics. Here, for example, is the text of a love letter written by the "MUK" electronic machine of the University of Massachusetts:

> *"My little treasure! My persuasive affection miraculously attracts your tender delight. You are my loving adoration, my heart-straining adoration. My brotherly feeling with bated breath awaits your dear impatience. My adoration of love tenderly awaits your avid ardor. Your miserable MUK."*

This text can evoke nothing but an ironical smile. However if the machine had written this text in the form of blank or rhyming verse, then the detection of its primitiveness would have probably been somewhat more difficult. Many absurdities may be concealed by the arbitrariness of poetic language.

The machine may be an investigative tool, useful for the analysis of verse and for the clarification of its formal and structural peculiarities, but it cannot be a poet.

ALMOST FANTASY

THERMODYNAMICS, INFORMATION AND THOUGHT

Candidate of Physicomathematical Sciences A. Mitskevich

Where is the Mechanism of Thought Located?

What does a man think with? The assertion that a man thinks with his head has already become an ironic truism, and doubts concerning the relative correctness of this assertion have been laid aside long ago. However during the course of the current century the question has been discussed in two ways: in connection with the problem of the "head of Professor Dowell" and in connection with the appearance of "thinking" machines. An analysis of the possibility of thinking with the head, separated from the whole organism, somewhat complicated the understanding of the problem, for it was clear that in the process of thinking not only the brain but also the entire nervous system takes part, for which the cortex of the brain is a sort of "control panel."

In a word, it seems that the *entire* man thinks, rather than a particular part of him. This is also confirmed by the fact that numerous attempts to localize the "thinking organ" in the brain have proved to be unsuccessful.

"Thinking" machines have forced an examination of the problem from another aspect: is it required that the seat of thinking have a biological nature or is there no fundamental significance in the material from which the organ of thought is created? Can these organs be semiconductor diodes and triodes, radio tubes or pneumatic elements of computers?

In the stormy discussion relating to the possibility of creating a "thinking" machine from non-biological elements, the ultra-cyberneticists have completely excluded from consideration *consciousness* and have concentrated their attention on the final result, i.e., on a conclusion which could have been reached by an electronic machine supplied with a reliable volume of initial information and the algorithm for its processing. The expression "information processing" has somehow become a synonym for thought, although this is not at all the case.

However this is done, the cortex of the human brain has a decisive role in the process of thinking and science is probably faced with a deeper understanding of this role, although in no case a negation of it. The adherents of the "thinking" machine do not without reason exclude from their consideration the individual spiritual qualities of man and machine, while declaring that these are outside the competence of science, since no one can "crawl into another spirit", machine or living, and convince himself that it thinks. Acknowledgement of the capability of "strange brains" to think is more a question of polite agreement rather than one of scientific proof.

Atoms, Molecules and Brains

It is known to everyone that man and naturally all the parts of his body consist of atoms and molecules. Far-ranging conclusions have been made, based on this circumstance.

Based on the atomic-molecular structure of the brain, the American mathemetician McCulloch, for example, wrote, "Since nature has already given us a working model, it is not necessary for us to ask whether it is possible theoretically to build a machine which processes information in a manner similar to the brain."

In other words, the atomic-molecular structure of the brain somehow guarantees the 100% possibility of constructing an artificial brain. It is true that the scholar left a logical loophole, in speaking only of machines "which process information, in a manner similar to the brain."

Another and no less violent advocate of machine thinking, W. Ashby, in his book "The Structure of the Human Brain" maintains that knowledge of "elementary physicochemical events in the living organism" are sufficient for describing all biological phenomena.

Thinking is doubtless a biological phenomenon and therefore it must fall under an atomic-molecular description. But when science established that the DNA and RNA complex molecules were capable of fulfilling the function of storing and transmitting information, this to an even greater extent confirmed the belief that complex information processes, including thinking, are accomplished by atomic-molecular mechanisms.

However, Lenin once expressed himself with insight against the possibility of the vulger-mathematical description of complex natural phenomena. This must always be remembered, especially if we speak about such a complex and mysterious phenomena as the intellectual activity of man.

In 1966 Doctor of Chemical Sciences N. I. Kobozev came to a conclusion which raised the question anew concerning the origin of thought in man[1]. So that the hypothesis of N. I. Kobozev is clear, it is necessary to analyze a question from the point of view of thermodynamics--the most general science of molecular-kinetic systems. If informational and thought activity is in fact associated with atomic-molecular mechanisms, then all the laws of thermodynamics and in particular, the law of the conservation of energy and the law of increasing entropy must be extended to this activity. The atoms and molecules of the brain are at a temperature of approximately 310°K and therefore remain under intensive thermal motion. The work of information and of thinking somehow contradicts the chaotic "Brownization" of atoms and molecules and imparts a directive nature to the process.

Thus the problem consists of the following: how does the Brownian atomic-molecular system, which the brain presumably resembles in the thermodynamic sense, "fit" with known regularities in information and thinking?

Entropy and Information

Entropy is one of the complex concepts of thermodynamics which often places students at a dead end. In processes which occur without a supplementary source of energy from without (isoenergetic processes), the decrease in internal system energy is accompanied by a proportional increase in entropy and vice versa. In all known spontaneous physical processes entropy attempts to increase and this fact was the reason for the intensive analysis of entropy. Such an analysis was fulfilled in the last century by Boltzmann. Thus entropy expresses the probability of a given state for a physical system.

What does this mean?

Atoms and molecules take part in any physical, chemical or biological process. At each instant their thermal motion creates a situation (state), not resembling the state which occurred a second ago. Thus entropy is a measure of the passage of a body, or of a system of bodies, from a less probable state to a more probable state, or from a less stable to a more stable condition. In this connection entropy increases.

[1]Kobozev, N. I., "The Physicochemical Modeling of Information and Thinking Processes", Zhurnal Fizicheskoy Khimii, No. 2, 1966.

The increase in entropy is not something mysterious. It arises naturally from the atomic-molecular structure of all the bodies in the universe, and since atoms and molecules always remain in motion, they attempt to scatter in infinite space. This will not occur only under one condition and that is if all thermal motion ceases, i.e., at the temperature of absolute zero. Then entropy is diminished is zero. But this will never occur in nature.

Since entropy is considered a measure of the probability of a physical system, and its increase is a passage from greater to lesser order, we can make a number of generalizations. The most important of these is associated with the concept of the theory of information. In the theory of information, similar to thermodynamics, a value is introduced which introduced which represents a measure of information associated with the probability of logical judgment concerning the system, and this value is also called entropy. The matter here concerns not only a formal analogy. The relationship between system entropy and information, i.e., the knowledge of its state, is quite profound.

Let us imagine a vessel filled with hydrogen. With this volume of gas it is possible to accomplish a number of experiments in order to define its temperature, pressure and to show that all the atoms accomplish thermal motion in a given segment of space. By the same token we can obtain certain information concerning the gas examined.

What would happen if the vessel is open and we make it possible for the hydrogen atoms to mix with the surrounding air? The entropy of the gas will begin to increase continually, while our information concerning it will become more indefinite with each second, until we completely "lose sight of it", i.e., we cease to know anything at all definite about it! Thus system information decreases with an increase in entropy!

In order to reduce both concepts to one form, information is measured, just as we measure entropy, but with a "minus" sign. In an analogy with thermodynamic entropy, in order to reduce the degree of uncertainty in the system it is also necessary to accomplish work, i.e., the work of obtaining information.

A Thermodynamic Model of Information

Human consciousness is a storehouse of diverse information, obtained as a result of experience or due to teaching. This information is used each instant by man in the course of his cognitive life. It is necessary to him for the fulfilment of the most diverse working tasks. Each second he extracts from this gigantic warehouse the required information, while "forgetting" about the tremendous quantity of other information which he may require at other moments of his life.

While extracting specific information from his consciousness, man reduces the entropy of the entire system while accomplishing work precisely equal to the reduction in initial entropy. The consciousness, in which information is stored, may be represented in the form of a certain volume where information is distributed in a specific manner (for example, "recorded" in RNA molecules). Up until the moment when man by strength of will selects from his storehouse information which is specific and which he requires at a given moment, the position of this information is reminescent of the position of an acquaintance whose address we do not know. After completion of the information work, man extracts from his consciousness the required data, which corresponds to the transformation of the system into a completely single-valued state, when the consciousness is fixed on only one "outcome" (i.e., on a specific address).

These analogies permit us to create a model of consciousness, while examining it in the form of a certain volume, filled with a hypothetical "chance-gas", each particle of which represents one of the possible outcomes of an information search. The selection of the required information is reduced to the conversion of all "chance-particles" into one and the compression of the entire volume to a value which uniquely corresponds to the information required.

A calculation of the thermodynamic work for such a "change-gas" leads to a value which corresponds precisely with the information work, calculated by the American scholars Shannon and Wiener based on the general theory of information. The modeling of information in the form of an ideal "change-gas" leads to conclusions which agree with the theory of information, and it follows from this that all informational processes may be accomplished on the atomic-molecular level.

A Thermodynamic Model of Thought

Information, in contrast to thought, cannot appear as a product of pure deduction from other data. It is impossible, not having expended any work, to simply stand aside and by means of "pure" reasoning to know the address of an acquaintance. It is impossible to establish by means of deduction where a specific gas molecule is located within a given volume.

Logically informational data are independent of each other, as if the selection of "primary", independent information were selected from nowhere (in physicochemistry, this is a "system of noninteracting particles").

Thought (particularly in its limited, formal-logical form) operates with informational data according to the laws of logic and this is reminescent of the chemical reaction of "heterogeneous" particles of a gas mixture which enter into a reaction according to strictly defined laws. The result of thought is conclusion, which can be recorded. This includes various elements of initial information. "Thought arises," N. I. Kobozev believes, "where the act of judgment begins, as a result of the cognitive selection of initial data or messages in the form of certain data (information), self-evident position (axioms) or specific assumptions (hypotheses) and the application to them of a certain algorithm which is constructed in agreement with the laws of logic."

With a given system of information, axioms and hypotheses, the process of thought always leads to a single-valued conclusion. This is a very important property of thought. It is similar to a certain spontaneous process, the outcome of which is independent of the physical and chemical properties of the medium in which it occurs and is always the same.

This is like movement down a hill along a railroad. The point of arrival does not depend on anything. It is determined only by the attempt of the system to pass to a stable state.

The final result of the thinking act is a conclusion or a deduction and is the stable state of the consciousness in the thermodynamic sense of this word.

The amazing uniqueness of the final result of thinking activity proves its strictly directed, (spontaneous), vector nature, which apparently does not depend on the chaos of Brownian movement of the atoms and molecules which make up the matter of the brain, or any other mechanism where thought occurs. A deduction may be repeated an infinite number of times with the same result. For example, the proof of the Pythagorast theorem may be repeated as many times as desired. This means that probability in a thermodynamic system, which accomplishes a thinking process, is always equal to unity, which corresponds to a single possible state of the microparticles responsible for thought and to complete order and nonsusceptiblity to thermal chaos.

Therefore, logical judgments are fundamentally without entropy (ordered and single-valued). Physically this corresponds to only one condition: the particles from which the thinking apparatus is constructed must be at a temperature of absolute zero!

"From this," says N. I. Kobozev, "comes a conclusion of fundamental importance: the thought mechanism cannot be located at an atomic-molecular level through particles known to us."

The scholar accompanies this conclusion with a remark of particular significance. Having rejected electron gas of high density as being "responsible" for thought, he writes:

"However it is not possible to believe that all forms of particles and statistics are exhausted and that new, light particles will not be found with properties and statistics which provide for lack of entropy in connection with their combination at ordinary temperatures and at low density. The neutrino with half-integral spin (fermion), with no charge and with zero mass already seems to approach these requirements."

Fantasy and Hypothesis

In 1962 I wrote a scientific-fantasy pamphlet "Direct Proof", in which a certain theoretical physicist, having examined all of the "objective" properties of the soul --its immortality, indestructability, omnipresence, etc., came to the conclusion that the neutrino was the single particle from which the soul could be constructed. This particle has zero mass and zero charge, its lifetime is infinite and its interaction with ordinary matter is practically nonexistent.

Of course this was a conjecture in jest. However, there are more serious arguments against the neutrino.. In order to think we require initial information which, as pointed out above, is "recorded" at the atomic-molecular level. Therefore with every act of thinking the neutrino must interact with atoms and molecules. However, calculations reveal that the probability of such reaction is insignificantly small and increases with an increase in neutrino energy. What kind of energy must these particles possess in order to accomplish clearly and uniquely the process which occurs continuously in our brain?

Laying aside the question of the interaction of the neutrino with atoms and molecules, we must direct our attention to the fact that this particle has a characteristic rotation (spin). The fact that the spin of an elementary atomic particle is somehow associated with the process of thought was expressed as a hypothesis by the English scholar Bowen as early as 1961. He formulated a certain new principle--the principle of derivitiveness, in agreement with which all observable macroscopic properties of bodies must be derived from the elementary properties of atomic particles. The charges of particles correspond to electrical currents, the energy levels of atoms correspond to the properties of solid bodies, kinetic energy and momentum correspond to temperature and pressure, etc.

In what macroscopic phenomena is spin reflected? "In thought," answers Bowen.

"Searches for thought" at the level of elementary atomic particles are nothing new in contemporary science. If we are successful in showing by direct experiment that the hypothesis discussed here is correct, then all problems associated with biological science, especially with biochemistry, will have to be examined from a completely different point of view.

It may prove to be the case that intimate phenomena of life are not limited by the summation of elementary physicochemical processes, thus many so-called puzzling phenomena in organic nature will cease to be puzzling.

The heart of the matter is not so much in proving or refuting the presence of certain puzzling phenomena, but rather in the development of completely new methods of approach to an objective, psychic investigation.

MACHINES OF THE FUTURE

Academician A. Dorodnitsys

In our century of technology the problem of the interrelationship of man and machine occupies the intellect of scholars, school children, sociologists, writers, philosophers, in a word, of all people, who are "not filled by bread alone." This is the natural influence of intensive technological progress, and this is the curious part of it.

Rapid progress is characteristic for the most diverse branches of technology, but there is only one type of machine which is associated with the question of its relationship to man--the question is one which may be coarsely formulated as follows: who will be the victor?

In fact, everyone knows that turbogenerators are produced with power ratings of 500,000 kilowatts and above. At maximum voltage a man may develop an output of only 1/10 kilowatt; this means that the machine replaces the physical power of 5 million people. However, no one fears the power of machines of this type.

The time passed long ago when people feared the steam locomotive (incidentally, it was also feared not because of its operating speed, but by virtue of a certain illusion of noncontrollability). It has been clear for some time that any powerful machine, if it may be expressed in this way, will inevitably be subordinate to man and will not be placed in operation without him (even if this is the most powerful and fearful military machine).

It seems that even the most inoffensive thing--an electronic computer, which quietly stands in a room, seems to man to be uncontrollable and therefore fearful in itself. The fact is computers represent a new quality in comparison with everything that man has invented in the past. They do not amplify the physical strength of man, but amplify his intellect.

For the present, computers are making their first steps. They simply count and carry out the simplest logical operations. They remain completely without wills, and do only what man orders them to do.

Nevertheless, it is already clear that in principle man can entrust these machines with any computational work. No one has any doubts on this account. Moreover, it is known that it is also possible to create machines which have inherent senses.

The simplest senses are physical sensations. A machine may perceive these differentially. A machine which is equipped with all possible acoustic, optical, and thermal devices (similar to our sense organs), may perceive the environmental situation and evaluate it. But this, of course, is only under the condition that the designer provides the machine with these properties, i.e., he introduces into the design of the machine the appropriate devices.

The problem of perception may be regarded as technically solved. Now many mathematicians and cyberneticists are occupied with the problem of the recognition of images by a machine. The machine itself must recognize the specific image which it has perceived. There are machines which recognize printed text, letters, and sounds. It may be arranged so that these images which are perceived and encoded by the machine will be associated in it with specific emotions. Depending on the nature of the perceptions and their evaluation, the machine will undertake certain actions. It is possible to include a will in the machine--to include in its program a specific goal for the existence of a given machine.

Thus in all aspects the machine may become a model of man.

Now only a few people doubt the possibility of achieving this. Marxism maintains that we will learn to apprehend the world, and that all processes in it have a material basis. Psychic processes also have a material basis and are capable of being understood, which means that they may be reproduced. Moreover, since processes in technology may be more rapid than biological processes, this means that an artificial brain may be constructed which is improved over our own.

Thus thinking automatons and robots are possible. Machines are also fundamentally possible which oppose man. From this fundamental possibility arise sociological theories of semi-fantastic nature to the effect that in the future a society of machines will arise which will enslave humanity. Such theories have found a reflection in the pessimistic novels of science fiction writers. This is an escape from living life. In addition, it is a complete inability to distinguish abstract possibilities from real ones, which are determined by real conditions in the creation of a machine, and by the laws of progress.

Of course everything does not occur in life as primitively as in fantastic novels. It is only according to the will of the writers that a certain great inventor, such as Captain Nemo or the invisible man creates alone a certain special super-machine. This does not occur in life. Machines are not created by individual people, but by humanity. They are also not created by one small laboratory, but by huge collectives.

Let us assume that in our country there is a brilliant designer of computers, Sergey Alekseyevich Lebedev. We all admire his talent and love for work. But even he could do nothing if he were alone, without his large collective (how many large institutes are occupied with the development of the physical and technological bases for machines!). It would hardly be possible to plunge them all into collective suicide.

Of course since states exist in the world where society is divided into antagonistic classes, it may be possible to find groups of people and even states which would want to employ the power of machines to harm mankind. But humanity would also be able to curb these machines. History shows that even when machines have been created for the anhiliation of man, after subsequent development they have nevertheless become our helpers.

Let us take aircraft, for example. At first they were employed at fronts in order to destroy man. But now aircraft properly and peacefully serve the people. Rockets also found their first application in war, but now work in meteorology, in topography and in communications. The investigation of space by rockets is a peaceful work. Even the splitting of the atom has become a peaceful work. After the bomb came the electrical power station. This has occurred because the power of the atom is not controlled by Nemo alone. Humanity invariably proves to be more clever and stronger than individual personalities and in the final analysis transforms into a peaceful tool even that which has been created with malicious intent.

I hope, however, that electronic computers are not forced to change their profession and to transform themselves from friends into enemies. Apparently thinking robots will be created when humanity shows significant social improvement over the present time.

But if machines will have an inherent will, will they not transform themselves into the enemies of man? No, man is in a position reliably to provide for the subordination of the machines, having given them from the very beginning the purposeful structure required. Let us assume that some very clever dogs correctly and conscientiously serve man. Even when man beats a dog, the dog nevertheless loves him and serves him (remember

Chekhov's Kashtanka, who ran away from a kind master for a worse one, because he was the first one to whom the dog became attached). The dog sacrifices himself in favor of his master, and the interest of the master are invariably placed ahead of his own. It is the nature of the dog to become attached to man--it is placed in his program.

This attachment is one of the emotions which can be fully reproduced in a machine. This is how the creators of machines will act if they are normal, human people.

The development of man, his properties--both the bad ones and the good ones--all these are caused by the instinct of self preservation. This is a basic, universal purpose of humanity, an instinct which has developed over billions of years of the history of the earth. Apparently with the aid of natural selection, only those survived in which this purpose was strong. Mankind cannot put an end to this instinct; while controlling him, it will necessarily save him from machines by placing in them the same simple idea, the same purpose, directed toward the preservation of the masters. Man creates machines with feedback. The feedback will be directed toward permitting the machine itself to find the path for the fulfilment of its main purpose, as defined by man.

This is why I do not fear at all the era of "thinking" machines. In fact I think that they will significantly increase the capability of man. Even now the machines are doing a great deal. The new technology will simply be impossible without them. The capitalistic countries are already attempting to avoid crises through the use of machines. With their help analyses and predictions of market conjunctures are accomplished, as are analyses and predictions of commodity demand. To a certain extent this permits firms to adapt in advance to anticipated changes. Of course it is difficult now to evaluate what the result will be of such a use of machines, since the effect of these predictions is masked by the narcotic injections of tremendous military orders into the economy. In socialistic states the machines help to organize an absolutely non-deficient economy, and make optimal planning of the economy possible.

It is quite possible that in the future machines will possess emotions, and this will further increase their capabilities. Emotions were given to man by nature for the most rapid achievement of his aims under difficult conditions, such as, let us say, under conditions of insufficient information and insufficient time for meaningful analysis of a situation.

The problem of modeling the psyche includes the modeling of emotion. In this connection the attempts to model creativity are interesting. Let us assume that a machine may compose melodies. Sometimes we shall obtain primitive boogie-woogie, but sometimes the results will not be bad.

Probably if we give the machine inspiration it will create quite good music. Unfortunately, however, for the present we do not know what the secret of inspiration consists of. I am not a poet and not a composer and will therefore not take it upon myself to judge how inspiration comes to them. The essence of inspiration in scientific work is more understandable to me. The scientist becomes interested in a certain problem, thinks about it a great deal, gradually accumulates information associated with the problem, and searches for methods to solve it. This process of the accumulation of information extends for a long time--many months, or perhaps for many years. But then, finally, the accumulated information reaches the required level and then the solution of the problem becomes clear.

Naturally the scholar experiences a feeling of joy, which is transformed, perhaps, even into ecstacy; he forgets about everything around him, and becomes completely enmeshed in his work and for many days does things which it appears that years have been wasted on previously. We are speaking of that state of the scholar--"the inspiration has come." If we analyze this without illusions, then it appears that a transition from quantity to quality has occurred: the accumulation of information has reached a level required for problem solution. The accumulation of information and experience plus a specific aim and desire--all this may be programmed into a machine.

Of course, our future creations will little resemble contemporary computers. They will differ from these much more than the arithmometer differs from the most advanced contemporary machine.

But the only people who are frightened of this are those who hold the intellect and will of man in low esteem.

IN THE SYMBOIOSIS WITH THE ROBOT

Doctor of Physicomathematical Sciences K. Fialkovskiy (Poland)

A basic question, and one which is not new, which has received special significance during the development of electronic-logical devices, is as follows: "Can a machine think?" In order to answer this question accurately, first we must insofar as possible clearly define what we mean by the word "think." In the context cited this question evokes many supplementary problems which in turn leads to innumerable discussions, but not always to unambiguous conclusions. It seems to me that a different statement of the problem would be more successful: "Is is possible to create a device, the capabilities of which will be comparable to the capabilities of the human brain?" One such device, as we know, already operates; this is the human brain itself.

Naturally, everything depends on individual views on similar questions; however, in any case in my opinion in the process of the evolutionary formation of the human brain there were no conditions impossible to repeat. Therefore, in undertaking work in this direction, we must clearly assume that a solution to the problem of creating a thinking device is only a question of time. If we accept as a prototype the nervous systems of the simplest animals, the evolutionary process of the formation of the device which interests us extended for more than billions of years. However it should be remembered that our civilization, in solving the problem of the creation of a brain, has available in comparison with evolution, immeasurably greater capabilities. First, it does not act with the evolutionary method of trial and error which certainly was not a confluence of happy circumstances in the process of the formation of the brain. In addition, it has before it a functioning model of one possible solution and studies the operating principles of this model. Nevertheless I suggest that even under these conditions, with the maintenance of the contemporary tempo in investigations, a constructive solution of a device for information processing, the capabilities of which will be comparable to the capabilities of the human brain, is a question of hundreds rather than tens of years. Perhaps I am a pessimist.

Of course the number of intermediate problems which must be solved is huge. I shall discuss one, and that is the problem of a memory of appropriate capacity. Norbert Wiener foresaw that this problem might be solved by means of utilizing memories for machines created on the basis of nucleic acids, i.e., memories which utilize the same information carrier as in the genetic memory of animals.

In contrast to the memory problem, which may be considered a problem of a technical nature, problems in the logical structure of the device also exist. John von Neumann, the creator of the theory of games and of the arithmetical-logic principles of contemporary computers, maintained that the language of mathematics and logic to which we are accustomed, is secondary and arbitrary in comparison with the arithmetical-logical language which the brain employs. The search for this "language of the brain" is of fundamental importance in the development of work on "thinking" machines.

I suggest that the study of the processing of information by our brain will lead to a reexamination of a number of our thinking habits, which we are inclined to consider as a certain type of absolute law. Thus the assertion of von Neumann that the language of mathematics which we employ is not an absolute logical necessity, but only a historically caused accidental form of expression, possible throws a new light on the arithmetical-logical bases of our contemporary computers.

Another problem which is also associated with future devices intended for information processing in the widest sense of the word, is the problem of the limits of the capability of the human brain.

If methods exist for the creation of a device, the capabilities of which are comparable to the capabilities of our brains, then the question asks itself: is it possible to create a device which is improved over the brain? This question collides with a conviction which is deeply rooted in our consciousness that our brain represents a device of ideal dimensions. However, this opinion is simply a conclusion from assumptions, as if we were in a state to solve any problem no matter how complex. Any problem?

A more frequently encountered argument in favor of a limitation in the capability of our brain is the fact that the brain consists of a finite number of elements, which therefore must have only a limited number of interrelations, i.e., to accomplish only a finite number of actions.

This argument, although it is also employed as support for the validity of the thesis, does not convince me for the reason that although the quantity of connections and values are finite, nevertheless to isolate clearly the individual physicochemical states of these connections is not very simple.

Much more convincing, as far as I am concerned, is the argument which is based on the evolutionary conditions of brain formation. In the final analysis the stages of evolution for the information processing device which is our brain were determined exclusively by the environmental conditions which surrounded our ancestors. In examining the questions statistically, we may say that only a brain which might provide for the optimum adaptation to existing conditions reproduced further as a result of the existence of a given type. From this comes our intuitive sensation of the laws of geometry, so necessary for the resultant throwing of the rock or for a selection of the optimum escape route.

Of course this type of evolutionary formation of our brain was characteristic of a transient period in the establishment of man, when he was shaped by his environment. The human period, characterized by adaptation of the environment to man doubtless also evoked specific evolutionary transformations of our brain. However, just as in the preceding period, these transformations flowed from actions in a specific ground environment. Therefore we may assume that from an evolutionary point of view the human brain is a specialized device for information processing under the conditions of a given earth environment. Perhaps the process of evolutionary adaptation of the brain to new conditions also continues now but in comparison with the rate of the development of technology it occurs so slowly that it need not be considered. In the final analysis, conditionally speaking, there is no difference between the thinking capabilities of contemporary man and the thinking capabilities of the ancient Greeks or Egyptians.

The developing technology of today has already placed before our brain problems which it is not in a position to solve. The driver of an automobile during rush hours, not mentioning the piloting of a jet aircraft, works at the limit of the capabilities of the human brain. At this point we are speaking of a specific limit--a limit on the speed of making logical decisions. A way out of this situation is comparatively simple: in border cases the functions of the driver or of the pilot are assumed by a machine, for example, by an autopilot. With respect to the autopilot we have no observations. We consider that here the machine will stay in its place.

And if we reach the limits of the conceptual possibilities of man? It would be unfounded anthropocentrism to maintain that our brain, a specialized organ adapted for information processing under conditions on earth, the third planet of the Solar System, is capable of solving any problem which humanity encounters in studying space and the atom. The fact that in the 60's of the XX Century, our brain, sporadically supported by primitive automatons, copes with rocket construction, the composition of music, the control of the national economy, and with theoretical physics, does not in any measure prove that this will be eternal. This is rather a successful confluence of circumstances. Perhaps the potential possibilities of information processing, concealed in our brain, will be sufficient for a certain period. However, for how long? Problems are already noted today which are briefly termed the "information barrier", the existence of which was not foreseen by the preceding generation. Perhaps a "conceptual barrier" will be raised before the next generation?

Of course, the way out of this situation will be through devices for information processing in the same broad sense in which our brain is such a device. Obviously these will be devices more specialized than our brains and in specific areas of problems improved over them; in other areas these devices will not have the capabilities of our brain. This is presented as the most rational concept of all those possible, in any case, from the point of view of contemporary man.

When machines of type appear we shall find before us a quite serious problem--that of man-machine relationships. In his last interview given shortly before his death, Wiener warned against the creation of machines not controllable by man. In this connection he had in mind basically machines which decided the fate of man or even of society without the participation of man. Perhaps such machines will not be created; however, when the machines appear, capable of independently formulating problems, in the sense that they will not be problems foreseen by their designers, the machines, capable of improving their activity on the basis of information obtained (experience) will result in the fact that the existence of humanity with such machines will become problem No. 1 in our civilization.

Hypotheses on this subject--the possibility of similar co-existence--have been put forward by many people: these range from machines which are the obedient tools of man, and which differ in no respect from the lathe or the automobile, to a struggle between humanity and automatons, inclusive. These extreme points of view appear to me to be unjustified; first, because before the matter could reach the stage of a struggle, an era must occur during which man would have the capability of coming to the conclusion that the further development of his child may prove to be unsafe. Perhaps he would not want to make this conclusion and then all decisions, as Wiener said, would remain in the hands of the "Iron Ian."

As far as the problems of man-machine relations are concerned, I have my own characteristic point of view, which of course is only one of all possible hypotheses. However it follows from this hypothesis that the struggle between man and automatons is impossible. I personally do not believe in the possibility of such a collision. I also do not believe that automatons with capabilities for self-improvement programmed into them and with the capability of independent problem formulation will be as simple to control as, for example, the automobile.

It seems to me that a way out of this situation has begun to appear un recent years. This avenue involved bioelectrical systems. A typical example in this case is the brain of a cat, which controls a rocket. The isolated head of a cat is observed on a screen, on which the object at which the rocket is aimed is projected, and the motor nerves are connected with the control engine of the rocket. The impulse is sent out by the brain, instead of setting the muscles of the cat in motion, set the rocket engines in motion. I. N. Kelly foresees the use of similar bioelectrical systems in the 1980's for space flights and in the far more distant future he sees prospects for the realization of more complex systems of this type.

The question arises: is not the bioelectrical system itself a solution to the problem of the co-existence of man and automaton? *Is this not co-existence by means of symbiosis?*

On the one hand, connected directly with devices for information processing, finds the capability of mental operations over a great quantity of data at speeds which contemporary man cannot even dream of, and on the other hand the problem of conflict with automatons disappears for with this type of symbiosis it would not be possible to determine whether a device which processes information is an automaton or a man in the contemporary meaning of this word. Such a question would simply have no meaning.

If this does in fact occur a new man and a new humanity will arise which have little in common with us. However, this humanity will be much better adapted to knowledge of the environment.

Could this be conformity with law, in that it is an evolutionary regularity in the adaptation of protein structures to life in space?

THE CYBORG--MAN OF THE SPACE AGE

Candidate of Philosophical Sciences I. Akchurin

This hypothesis is the child of bionics, of contemporary astronautics and cybernetic medicine. It speaks about the pads of human evolution and in addition, raises profound philosophical questions: these include establishment of the limit within which it is permissible for science to interfere in human existence, and where the area begins in which no one has the right to intrude, including all humanity as a whole, and even with the kindest of intentions.

These questions are very difficult to solve. The best intellects have thought about these for a long time, but up to this time from an aspect purely theoretical and philosophical. Now these problems are raised for surgeons, biologists and engineers as practical problems in space and cybernetic technology of the contemporary and future ages.

Briefly put, the idea of "technical modernization" of material existence consists of the following. Already engineer-medical workers have constructed an artificial heart, created artificial lungs, artificial kidneys and other completely reliable electron-mechanical "substitutes"...

Pages 304-305 are missing from the original text submitted for translation.

...The nerve cells make up a completely insignificant share of those neurons which they obtained at birth. As a practical matter the prolonging of human life with an artificial body will require several thousands of years, if not more...

We shall not personify here the other side--that of the enemies of the cyborgation of people. This is simply because it is almost certain that each of us at first acquaintance with this hypothesis involuntarily and for a certain period of time remained in this group ourselves; this hypothesis at first evokes something similar to an emotional shock. Immediately arguments of the following type come into ones head: "We cannot interfere so deeply in the nature of human existence", "No one has the right to carry out such anti-human experiments, even on himself", etc. But we then remember where we have read similar judgments and even with a certain awkwardness we do remember: almost the same words formed the basis for the prohibitions of the scholastics of the Middle Ages against anatomical investigations of the human body; this was said even by the Protestant fanatic Calvin, while sending to the bonfire Michael Servetus, who had given for the first time a correct concept of blood circulation in the human body.

Briefly put, in conjunction with all the prohibitions and objections against the interference of science in human nature, it is necessary to be more circumspect. To some extent we interfere in the operation of the human brain when we take a tablet of pyramidon for a headache. In this connection the extended consequences of such interference may be far from those usually predictable.

In general the cyborgation of people, the replacement of their organs with artificial ones will doubtlessly occur and continue to develop in contemporary medicine. Even at the initial stage this will bring relief from all kinds of suffering to a huge number of people and will even save their most valuable possession--their lives. A prohibition against this trend would be equal to a death sentence for many, many people.

As far as the question is concerned as to whether there is a fundamental boundary of permissible interference by man in his inherent nature and specifically where this boundary is located, this question certainly requires very serious scientific examination on the part of the entire complex of the sciences of man, including medicine, physiology, psychology, neurophysiology, and of course, sociology and philosophy.

MYTHS OF SCIENCE

Stanislav Lem (Poland)

Cybernetics has experienced two decades of life, and therefore it is a young science, but it is developing with amazing rapidity. It has its own schools and trends, its enthusiasts and skeptics; the former believe in its universality, and the latter seek limits for its application... Specialization has arisen in this science, just as in other sciences. Since each science creates a characteristic mythology, cybernetics has this as well. The mythology of science sounds like a contradiction, or an empirical irrationalism. Nevertheless each science, even the most exact, develop not only as a result of new theories and facts, but also due to the guesses and hopes of scholars. Development justifies these only partially. The remainder turn out to be illusions and thus become similar to myths. Classical mechanics had its myth in the form of the Laplace demon, who knew the instantaneous speeds and possession of all atoms of the universe, and could somehow predict their entire future... Now roaming about in cybernetics is the myth of the Middle Ages concerning the homunucleus--an artificially created intelligent being. The dispute concerning the possibility of creating an artificial brain which displays features of the human psyche, has frequently attracted philosophers and cyberneticists into its orbit. This is a fruitless dispute because the matter actually does not concern a reproduction of the human brain, but rather it concerns understanding the human brain.

Is it possible to transfer mercury into gold?--we ask an atomic scientist. Yes, he answered, but we do not occupy ourselves with this. Such a conversion is nonessential for us and does not influence the direction of our work.

Will it be possible sometime to construct an electronic brain--an exact copy of a living brain? Certainly it will, but no one will do it.

This means that we must distinguish possibilities from real goals. In science possibilities always have their "negative prophets." I have always been amazed at their number as well as with the vehemence with which they prove the impossibility of constructing flying machines, atomic or thinking machines...People who are drawn into fruitless discussions may easily lose sight of the real problems. The "antihomuncularists" are convinced by denying the possibility of a synthetic psyche, they protect the superiority of man over his creations, which in their view can never surpass human genius. Such a defense would at least have some meaning if someone in fact wanted to replace a man with a machine--not for a specific form of work, but within the framework of our entire civilization. But no one dreams of this. The affair also does not concern the construction of a synthetic humanity but it concerns only the opening of a new chapter in technology--of systems of an arbitrarily greater degree of complexity. Since man himself, his body and brain belong to this specific class of such systems, the new technology will recognize the complete power of man over himself, over his inherent organism, which in turn makes possible the realization of such an eternal dream of man as a craving for immortality, and perhaps even a transformation of processes which are today considered to be nonreversible (such as biological processes, and in particular that of aging). It is another matter that these aims may prove to be fictitious, as were the aims of the alchemists. Even if man can do everything it will probably not be with the best method. If he wants to do it he will achieve in the final analysis any aim, but perhaps it is still too early to grasp that the price which must be paid will make attainment of the goal an absurdity.

For we may establish for ourselves a final point, but the path to it is defined by nature. We may fly, but not with the aid of outstretched arms. We may walk on water but not in the way which the Bible represents. Perhaps we shall invent longevity which is practically equal to immortality, but for this it will be necessary to discard the solid shell which nature has given us. Perhaps due to anabiosis we shall be able to travel freely for millions of years--but those who awaken from a frozen sleep will find themselves in an alien world, or during the time of their inverse death, they will find that the world and the culture which forms them have disappeared. Thus in fulfilling our desires, the material world demands of us behavior which may make the fulfillment resemble either victory or harm.

Systems as complex as the brain or as society do not yield to description by the language...of simple laws. In this sense the theory of relativity and its mechanics are simple, but the mechanics of the thinking processes are no longer simple. Cybernetics concentrates its attention on these processes because it attempts to understand and to subordinate complex phenomena, and the brain is the most complex of material devices known to us. Of course it is certain that even more complex systems are possible. We shall recognize this when we learn how to construct them. Thus cybernetics is first of all a science concerning the achievement of aims which cannot be achieved by simple methods.

Cybernetics is occupied with such "schemes", not as a result of "homuncular" ambitions, but because it is preparing to solve design problems of a similar order. It is still very very far away from the chances of creating such a device. But it has existed now for only two decades. For its solutions evolution required more than two billion years. Let us assume that cybernetics will require still another one hundred or one thousand years in order to achieve this; for all of this, the difference in time still speaks in our favor.

As far as the "homuncularists" and the "antihomuncularists" are concerned, their quarrels...indicate the childhood or the young age of the new science and no traces of these will appear in its future development. There will be no artificial people because they are not required. There will be no "revolt" of thinking machines against man. The basis of this dream lies in another ancient myth or Satan, but no one intellectual amplifier will be an electronic anti-Christ. All of these myths have a common, anthropomorphic denominator, to which the thinking activities of machines must apparently be reduced. A true treasure house of stupidity! In fact we do not know whether automatons, in crossing a specific "threshold of complexity" will display signs of inherent "individuality." If this does happen their individuality will differ from the individuality of man just as the human body differs from an atomic reactor. We must be prepared for surprises, troubles and disturbances which we are not able to imagine today but not to the technical masks of demons and to evil spirits of the Middle Ages.