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THE CONCEPT OF THOUGHT AND CYBERNETICS

-USSR-

by P.V. Kopnin

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THE CONCEPT OF THOUGHT AND CYBERNETICS

-USSR-

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The development of science poses before philosophy a number of important problems connected with the elaboration and concrete definition of basic concepts and categories in dialectical materialism. Our literature has for a long time and with a definite degree of success been developing the philosophical problems of modern physics and generalizing epistemologically the results of quantum mechanics, the theory of relativity, and other physical discoveries. To a somewhat lesser degree, our writers have been analyzing from the philosophical standpoint the discoveries of biology, chemistry, astronomy, etc.

In recent times, the attention of philosophical thought has been attracted to a new and promising field of scientific endeavor--cybernetics; the development of this field insistentlly poses the question of new epistemological conclusions. Such conclusions are already being drawn by many bourgeois thinkers; these conclusions have been such, however, as to stand in contradiction to the actual results of this science. The task of Marxists consists in drawing epistemological generalizations from the results of cybernetics which would follow in strict logical sequence from its actual laws and facts. The main issue here is not one of giving a correct philosophical explanation of this or that fact of cybernetics. This must be done and can be done by the scientists themselves, the majority of whom have in our country long ago realized the necessity for a dialectical-materialistic explanation of the laws and facts of science. Marxist philosophers must go further. The analysis of new facts and laws, particularly those revealed by cybernetics, necessarily demands the improvement and perfection of the

entire apparatus of philosophical science--its laws and categories, as well as the bringing into correspondence of these categories and laws with the results of modern science.

Cybernetics affords a large body of factual material for the elaboration and concrete definition of many positions assumed by dialectical materialism, in particular its teaching as regards the forms of material motion and their interconnection, the material unity of the world, and reflection as a property which lies at the foundation of matter.

Heretofore, the dialectical-materialistic understanding of thought has been based on the generalization of psychological, neuro-physiological, and linguistic data. It now becomes apparent, however, that cybernetics is destined to assume a significant role in the understanding of the nature and peculiarities of thought processes; this is the case despite the fact that cybernetics at first would appear to be far removed from these processes. The data provided by cybernetics permit one to pose the question of a more concrete and elaborate understanding of thought, such as is necessary for the development of a number of sciences, including cybernetics itself.

1. Man as the Subject of Thought

The category of thought, along with that of matter, is one of the fundamental concepts of dialectical materialism; its correct understanding determines the solutions to numerous cardinal problems both of philosophy itself and the natural sciences. The problem at hand is not one of obtaining composite data on thought processes from the various scientific fields, but rather in the development of their philosophical understanding so as to reveal the nature of thought in its relationship to matter. The philosophical understanding of thought serves as a method in the study of various aspects of thought processes by the specialized sciences.

To determine the nature of thought is not only to answer the question of whether it is material or ideal. Thought is a many-sided process. To say that it is an ideal mode is merely to reveal one of its aspects--the relationship of the result of thought to that object which is reflected in it. When we analyze thought from the epistemological standpoint, no Marxist can harbor any doubt that the cognitive mode which enables us to think stands in relation to the object reflected in it as the ideal to the material. The material and the ideal constitute a unity of opposites. Their opposition is absolute within the limits of epistemology, since the image of the object, being an ideal entity,

can in itself be invested with the properties of the object it reflects; it is capable merely of reflecting it with a lesser or greater degree of precision and fullness. Beyond the limits of epistemology, however, "to operate with the opposition of matter and spirit, the physical and the psychic, as an absolute opposition, would be a great error" (V.I. Lenin. Works, Vol. 14, page 233). The development of the natural sciences, the physiology of the higher nervous system and cybernetics in particular, demonstrates the relativity involved in opposing the physical and the psychic beyond the limits of epistemology.

Enormous importance for the philosophical understanding of the nature of thought is assumed by the establishment of the nature of the thinking subject. Thought arises as a result of the interaction of subject and object.

It is incorrect to identify the subject with the ideal, and to characterize the interaction of subject and object as a relationship between the ideal and the material. Idealism reduces the subject to thought, to the ego. Pre-Marxist materialism, particularly of the Feuerbach variety, held correctly that thought is not the subject but rather the predicate, a property of the subject as a material being, of man as a part of nature. Neglecting man's social nature, however, this form of materialism did not reveal the peculiarities of man as a thinking being.

Dialectical materialism, on the other hand, concedes the subject not only as man with his flesh, blood, and brains, but also as a being existing in a contextual relationship with the means of production and all of the social interrelationships entered into with fellow human beings. For this reason, the subject of cognition and practical activity is not man as an individual, but rather humanity at a specific level of its social development. Of course, humanity as a universal exists only in its particulars (in individual men); the particular (the individual man), however, includes within itself that universal which possesses real existence in the particular. Thought is a characteristic of the subject as a social being.

From the natural, scientific standpoint, thought may be defined as a property of the highly organized brain matter. The psychological and psychical categories reflect the relationship between thought and the brain; the psychical is a property of the physiological (thought is a function of the brain). As is known, a property is defined as a manifestation of a quality of an object in its relation to other objects in the process of their interaction. Interacting with external objects, the brain manifests its properties, one of which, namely thought, is qualitatively distinct from

all of the other brain properties.

Thought as a property of matter has much in common with its other properties. One usually emphasizes the specificity, the qualitative distinctiveness of this property of matter as apart from its other properties; this is indeed correct. In doing this, however, one should not forget about the inter-relatedness of all material properties, which is the basis of the principle of the material unity of the world.

Thought, just as any other property, arises as a result of the interaction of matter, without which there can be neither material properties nor states. F. Engels wrote: "Interaction is the first consideration in the perception of matter in motion from the standpoint of modern natural science.. Thus, science confirms Hegel's statement that interaction is the true *causa finalis* of things" (The Dialectic of Nature, 1955, pages 183-184). The specificity of thought as a property of matter is determined by the qualitative distinctiveness of the interacting systems (subject and object); this interaction nevertheless has much in common with any material interaction. This fact was pointed out by V.I. Lenin and defined as the reflective capability lying at "the base of the whole material structure".

Such a concept of cybernetics as information is of great importance in the concrete definition of the position assumed by V.I. Lenin as to the reflective capability peculiar to all matter. Thought is connected with the creation, transmission, and transformation of information; the process of informational transmission and transformation, however, takes place not only in the thinking brain, but also in other systems, such as electronic computers.

The kinship of thought with the reflective capability, which is a property of all forms and types of matter, serves as an objective base for the modelling of thought processes. There can be no doubt as to the possibility and timeliness of constructing physical brain models. The study of "electronic brain" functions is not only of scientific and technical interest, but of philosophical significance as well. It provides the necessary factual material for the confirmation of the thought expressed by V.I. Lenin that the reflective capability lying at the base of the structure of matter itself is akin to sensation, which is clearly connected with the activity of highly-organized organic matter. In stating this supposition, V.I. Lenin writes: "In actuality, there still remains the task of studying and investigating the manner whereby presumably non-existent matter interacts with matter consisting of the very same atoms (or electrons) and at the same time having a clearly apparent sensual capability. Materialism clearly poses this

as yet unsolved problem, thereby hastening its solution and further experimental investigation" (Works, Vol. 14, page 34).

Through the modelling of the higher nervous functions, cybernetics takes a definite step forward toward the solution of the problem posed by materialism. It establishes the kinship of the reflective capability exhibited by all matter, with sensation and even thought. The results of cybernetic studies show that the reflective capability in inorganic matter can rise from the status of a logical supposition as expressed by V.I. Lenin, to that of a scientific fact susceptible to experimental investigation. Science has only made a few strides, but we have already begun to comprehend the enormous vistas which will open up along this path.

Some physiologists are arguing against the establishment of a kinship between the conditioned-reflex activity of the human and "electronic" brain, branding it as a form of mechanistic thinking. A thinker who shares V.I. Lenin's hypotheses as to the reflective capability in any form of matter, however, must recognize this fact of science as a triumph for dialectical materialism. It is easy to understand the French physiologist P. Koss in his attempts to drive a wedge between thought and other properties of matter, since from his neo-Thomistic point of view, thought is an activity having its origin in a supernatural being. For materialistic physiology, however, the relationship between thought and other properties of matter must appear self-evident and stemming from two fundamental principles of materialistic dialectics--the material unity of the world and development. Thought is the highest level in the development of the reflective capability possessed by all matter.

But to emphasize the kinship and similarity of thought with other material properties is only one aspect of the matter, whose absolutisation can actually lead to mechanism, and thence to idealism. No less important is the other aspect--the qualitative distinctiveness of thought as a property of matter which one should never neglect in speaking of a comparison between the human brain and an electronic computer. Through the construction of physical models of the brain, it is possible to study thought to the same extent and degree, in which it is similar to other properties of matter. F. Engels wrote: "Some day, we will undoubtedly 'reduce' thought to molecular and chemical action in the brain by some experimental technique; but would this actually exhaust the essence of thought?" (The Dialectic of Nature, page 197).

Between the actual thought process and its physical model, there is the same distance as between the social and physical forms of material motion. In order to think,

matter must live not only biologically, but socially as well.

In the interesting book by Z. Rovenskiy, A. Uemov, and Ye. Uemova, entitled Machine and Thought (Moscow, Gospolipizdat, 1960) it is asserted, that an artificial brain could function as its natural counterpart if its elements possessed the properties of neurons. "In order to build a machine which would function like a brain", say the authors, "it would be necessary to build it of a material which would possess these properties--not of electronic tubes or semiconductor elements, but rather of highly-organized albuminous compounds such as constitute the brain" (page 139). Of course, the difference between electronic tubes or semiconductor elements on the one hand, and neurons constituting the human brain on the other, is enormous. This difference cannot be ignored. But let us suppose that biochemists produce a substance similar to neurons. Will this substance think? This question would be answered with a firm 'no', since thought is not only a property of highly-organized matter, but also the product of social history. No substance, even that having the most complex biological structure is the subject of practical activity and thought. Thought can arise only when the biological being becomes a social creature and enters into a new relationship with nature (transforming it) and other beings akin to himself.

For this reason, the study of the thought process through the construction of physical brain models is of extreme value, but only in the single connection of establishing the kinship between thought and that reflective capability which lies at the foundation of the structure of matter. It stops, however, at precisely the point where thought begins essentially as a result of the interaction of subject and object. The dialectic of subject and object interaction is the basis for understanding the peculiarities and qualitative distinctiveness of thought. Why was it that at one level of social development humanity thought in a specific manner, reflecting reality with such a degree of fullness and precision, while at another developmental level, its thought content was so divergent? The answer to this question cannot be obtained through the analysis of human brain structure by means of an investigation of changes in the quantity and quality of brain neurons. The answer lies rather in a totally different plane, in so far as thought is a specific form of man's spiritual activity which gives rise to the formation of concepts, theories, and ideas.

Karl Marx called thought a spiritual industry which was "originally woven directly into the material activity and material intercourse of men..." (Karl Marx and F. Engels,

Works, Vol. 3, 2nd edition, page 24). As a process of spiritual activity, the purpose of thought is to obtain new results, the creation of a cognitive mode which deeply and thoroughly reflects its object. A knowledge of the dialectic involved in the interrelation of the subject and object during the process of practical action and cognition is the key to the understanding of the essence of thought, and the laws governing its progression toward objective truth. Thought does not separate the subject from the object (man and nature), but rather unites them through the creation of a subjective image of the objective world.

The subjectivity of thought consists primarily in the fact that it always proceeds in man as a subject. There is no objective which is not connected with the activity of the subject, i.e., the man. Objective thought existing prior to and independent of a man is a fiction created by the objective idealists. The secret of this speculative hypothesis put forth by idealistic philosophy consists in its bifurcation of thought and its bearer (the subject) and its objective source (nature), and hence in the endowment of thought with independent and absolute status.

Furthermore, the result of thought is not the creation of the object itself as such with all of its properties, but rather of an image of the object. In the thought process, we are always dealing not with the object itself, but with its image.

Finally, the object in thought is reflected with differing degrees of fullness, adequacy, and depth of penetration into its essence. Thought does not exclude the possibility of one-sidedness in the reflection of its object, the alienation of ideas from reality, and distortion of the object image itself. The form of the object in thought depends on the subject, particularly on his position in society. As was pointed out by V.I. Lenin: "If we are to examine the relation of subject to object in logic, we must also take into account the general existential premises of the concrete subject (= the life of the man) in his objective surroundings" (Works, Vol. 38, page 194).

The level of social relationships determines the character of thought in a given epoch. Without an analysis of the social life and its contradictions, it is impossible to understand why the objective world is reflected in a given manner, form, and degree of depth and fullness.

Thought can be nothing other than the subjective image of the objective world. It cannot exceed the limits of subjectivity in the sense that it is always peculiar to the subject--the social man--and always creates only the image of an objective object, and is not itself such an

object with all of its properties. The development of thought proceeds along the creation of such an image which would fully and precisely reflect its object.

During the course of the development of his knowledge, man is ever more actively intervening in the process which serves as the object of his cognition. Man in general perceives the objective world in so far as it impinges upon him. The continually growing activity of the subject in the thought process manifests itself in various forms. In the first place, the thought process in man draws support from all previously acquired knowledge which is digested and fixed in the form of definite concepts, categories, and theories; these mental forms play the role of pivotal points in the mental derivation of new objective results. Even in its simplest form, thought is of a categoric character. As was noted by F. Engels, a man could not connect two facts in his mind without the aid of categories.

Furthermore, man approaches the study of objects forearmed with a number of pieces of apparatus, instruments, and devices, with whose aid he intervenes in processes, determines their effect on his instruments and devices, etc. It is difficult to conceive of modern scientific thought apart from its numerous instruments and devices with which the subject actively affects the objective process and gains knowledge of it. These devices are created by man on the basis of definite ideas and theories; the latter are, of course, not identical with the process under investigation and do not constitute any part of it. For example, there is no correspondence between the Wilson cloud chamber or a Geiger counter on the one hand, and the "elementary" particles on the other; the former are not a part of the latter.

Finally, thought as a spiritual activity is a purposeful mode, in so far as men engaged in the thinking process set definite goals which follow from the needs of their social existence.

All of this has to do with the categorical nature of thought; the utilization in the thought process of instruments and devices created by man himself, as well as the purposeful character of the thought process, testifies to the activity of the subject. Progress in thought is connected with the growing role of all of these factors: it is becoming ever more purposeful, technical means are becoming ever more plentiful, and theories, through constant refinement are securing an ever more important place in the progress of thought. This suggests the following question: might not these developments be giving rise to a greater degree of subjectivity and divergence from the object under

study? Such an interpretation of the heightened activity of the subject in cognition has had precedence in the history of philosophy; it is still encountered today. Thus, for example, the apriority and subjectivism of the epistemology expounded by Kant had as one of its sources a distorted and one-sided interpretation of the role of categories in the thought process, and it was precisely the categorical character of thought which served that philosopher as an argument for isolation from the external world and the so-called "things in themselves". In modern bourgeois philosophy, there exists a special brand of so-called instrumental idealism which speculates on the active role of the instrument (actually, the men who created it) in the process of learning about the objective world. As regards the purposefulness of the thought process, one might say that throughout the entire history of philosophy, it has served as an argument in support of the independence and autonomy of thought in relation to the objective world.

Actually, the heightened participation of the subject in the process of obtaining knowledge is a necessary condition for the progression of thought along the path of the discovery of objectively existing properties and laws. Passive contemplation by the subject of the object provides a sketchy and superficial type of knowledge which is subjective not only in form but in content; more precisely, it yields subjective opinion rather than true knowledge. The dialectic of the development of thought is such that the objective truth is gained by thought through the active participation of the subject, and in this sense knowledge is all the more objective in its content the higher its formal subjectivity and the greater the participation of the subject in the processes under investigation. Categories and theories with which the subject operates during the thought process are a means for revealing the actual nature of the object because they possess a degree of objective content themselves. And it is only because of this content that they become a method for the progression of thought toward the achievement of new concepts and theories, in which the object receives a more concrete and objective reflection.

2. "Machine Thought" as a Result of the Practical and Theoretical Participation of the Subject and a Tool of Further Thought Development

The general character of thought creates the necessary premises for the determination of the nature of so-called "machine thought" and its relation to true human thought. The achievement of clarity in respect to this problem is of

great importance not only to the struggle against idealistic speculations which tend to arise on the healthy body of cybernetics, but also for the positive development of this new field of science. Of course, the term "machine thought" and "thinking machines" are unfortunate since they tend to confuse the issue at hand. They have been introduced into the scientific vocabulary in connection with the development of cybernetics for the designation of functions taking place in electronic and other types of computers. Having as yet no well developed terminology of its own, cybernetics is obliged to operate with terms whose literal meaning does not correspond to the content of cybernetic concepts. That which is done by machines is, of course, not thought, and this is indeed understood by many foreign thinkers who are quite remote from Marxism [see note 1.]. [Note 1: for example, Pierre Latisle, in his book entitled Thought with the Aid of Machines notes, that for the explanation of the functions which take place in electronic computers, it is tempting to use the word "thought", but that the machine does not think, and there is no such phenomenon as mechanical thought. In general, the term "machine thought" has a right to exist only if it is understood to mean the creation of physical models of the thought process. But a model of thought is not thought itself.]

The question of whether machines think or not can arise only in minds either inclined to speculation or theoretical sensationalism. The actual scientific problem is of a completely different nature; it lies in the investigation of the relationship between "machine thought" and actual human thought, as well as in the determination of the place it occupies in the theoretical and practical mastery of the external world by man, and the purpose and basis of its origin.

We already established earlier, that man engages in productive endeavor, feels, and thinks in the creation of the tools which are the product of his practical and theoretical activity. The human eye observes, and the human brain thinks. The only subject of thought is man armed with all of the tools at his disposal at a given level of his development. This includes, indubitably not only the brain, but all of the means of production, machines, and devices whereby man transforms and comes to know the world. Computers in the given case do not constitute any exception. Any means of production extends and reinforces man's natural organs, whose possibilities are limited. The specific characteristic of electronic computers consists in the fact that they extend and reinforce man's brain; they are, in other words, tools of his mental rather than physical

activity. It is man that digs the earth and observes distant objects, and not the excavator or telescope; it is likewise man, and not the computer, who thinks. But just as modern physical work is carried out with the aid of the most complex tools and machines, mental work under the conditions of a developed civilization, advanced science, and technology is implemented with tools which directly (all of the tools aid in this matter indirectly) help man to think. These tools have been made to take on some of the functions which man has performed earlier through the thought process without their aid.

The problem as to the place of computers and their relation to the thought process has already been posed by F. Engels, who, in comparing the arithmometer with the operation of reason, wrote: "The reasoning faculty engaged in calculation is a computer! It is a curious conglomeration of mathematical operations admitting both of proof and test, since they are based on direct material contemplation although abstract, with such purely logical operations which admit of proof only by means of the syllogism, and which, consequently, are devoid of that positive certitude which characterizes mathematical operations.--after all, how many such calculations turn out to be erroneous!...They are nothing more than a routine pattern" (Anti-Duehring, 1957, page 318).

F. Engels termed the identification of the computer with the work of the human brain a curious conglomeration resting on a superficial analogy rooted in a misunderstanding of the essence and properties of thought. Any computer, even the most complex, is built on the basis of a circuit diagram (pattern), whose limits it cannot exceed. In it, the rich and meaningful thought process is represented in an impoverished, schematized form. Making use of the results of modern mathematical logic, which has distilled the simplest forms of logical connection, man has mechanized the standard process involved in the progression from one proposition to another. The machine helps man by relieving him of the mental labor involved in the process of logical derivation. Why can this process be mechanized to a certain degree? This is based on the fact that thought always takes place on some sort of sensory foundation--on "words and other sensory symbols", whose ideal meaning is connected with their material significance. We must note, furthermore, that we can operate with sensory symbols in the thought process according to definite laws, up to a certain point disregarding their significance. The computer has to deal not with ideal object images, but merely with various sensory symbols, operating only on their material content. The result of computer operation is a system of definite patches, signals, bells, etc. It is man, who in

the process of thinking with the aid of a computer, interprets the results of these symbols and connects them with definite meanings.

The computer does not perform an actual logical derivation in so far as this is connected with the understanding of the initial proposition and final results of the derivation. The machine merely simulates that part of the process which is connected with operations on thoughts as sensory symbols according to definite laws for which the machine has physical analogues. The machine can imitate and copy human thought up to a certain point. The computer itself, furthermore, bears the imprint of thought and social practice, since it is the result of human science and technology; the machine represents a concrete realization of the results of human thought. New scientific theories will give rise to new machines which will perform new functions, and will become an even more subtle method of penetrating into the secrets of nature and the thought process itself. To limit the progress of computer technology to a stage wherein it copies a certain part of the human thought process would be simply to wall in the development of human social practice and thought.

When the computer as a product of the practical activity and thought of man is separated from its subject and counterposed to him as an external, independent, and alien force, there arises the conception that the machine acts and thinks of and in itself. The alienation of the "thinking machine" as a product of human labor from man himself, and the transformation of it into an independent subject of thought, is a source of various speculations on the replacement of human thought by its more perfect computer counterpart, on the tyranny of the machine over man, on a "machine society" without men, etc. The social wellspring of all such speculations is the separation of man from the object of his labor and the act of production itself in a class society.

As a product of the practical and theoretical activity of man, the electronic computer represents merely a means and a device to be used in the advancement of thought. The subject of thought is man, who enters into an interaction with the object forearmed with his entire store of knowledge, as set down in the form of categories and theories, and making use of all of his various devices and instruments including modern computers.

The functioning of machines in simulation of the thought process has its own specific characteristics. The results of former human theoretical activity, known laws, and earlier theories are embodied in concrete form in the

computer. It is known that the progression of thought on the basis of its inner logic can take place either within the limits of concepts and theories formulated at an earlier time, that is, essentially, without the achievement of fundamentally new results, or else, exceeding the limits of former concepts, thought may proceed to the creation of new theoretical structures. It is only in the second case that there is an actual development of thought accompanied by the attainment of new results which constitute the cognitive essence of thought. Embodying the results of thought in a machine, it is possible to duplicate in it some portion of the thought process, such as is connected with its progression within a definite theory to the derivation of new results and consequences therefrom. This process of sequential derivation within the limits of a given theoretical construction take place with a certain degree of independence of man and thought; it is performed by the machine itself according to a given scheme or set of schemes.

In order to transfer some portion of the functions involved in the thought process to the machine, it is necessary to formalize knowledge, and to express the thought content in forms which can be subjected to formal transformations according to predetermined rules. On the surface, this formalized knowledge must appear in the form of a system of material sensory symbols, that is a peculiar type of artificial language. For this reason, the formalization of knowledge and the expression of thought content by means of logical formalisms or computer language systems is now assuming great importance. The progress of thought to a certain degree depends upon the success achieved in this area.

Modern scientific thought is characterized by a number of peculiarities which are distinct from thought in preceding epochs. This difference is primarily one of content. A more mature and developed mode of practice gives rise to correspondingly more refined thought which is capable of more precise, adequate, and full reflection of the external phenomenal world. Practice is introducing into the sphere of thought new objects, aspects, and laws which in earlier times did not represent objects of human investigation.

This change in the content of thought led to many other changes within it, including those of a formal and structural nature. Modern thought is diverging ever more widely from sensory concreteness, it is becoming less empirical emerging as an aggregate of numerous abstractions which tend to become extremely remote from the perceptual properties of an object. If scientific thought in the eighteenth and nineteenth centuries was largely empirical,

it is now acquiring a truly theoretical form. This, of course, does not mean that it is losing its contact with experiment and is becoming independent of it. On the contrary, the connection with experiment is becoming ever more intimate, although different in character. In the first place, experiment itself now differs greatly from its counterpart in the early days of science: to an ever greater extent, it is preceded by theoretical elaboration, serving to confirm the latter and to guide the advancement of new theory. In the second place, it is not experiment alone which is the source of new knowledge. Following the inner logic of its development, thought tends to arrive at results which not only have never been duplicated in any experiment, but are in principle not susceptible to direct duplication therein. Thought is surpassing experiment, and determining the future trends of its development. The interrelationship of theory and experiment is now at a level of great independence and activeness as regards thought; to a greater degree than ever, thought is guiding and surpassing experiment.

One index of the maturity of modern thought consists likewise in the fact that it is to an ever increasing extent engaged in self-realization and the probing of its own results. The creation of theories of theory and sciences of science is an indication of the high degree of maturity and great successes in understanding reality attained by thought. The greater the number of scientific theories on theory itself, the more perfect our thinking in coming to know the external material world. Self-realization is not an end in itself, but rather a means of developing and improving thought in the comprehension of the objective laws of nature and society.

Finally, another distinguishing characteristic of modern thought will be found in its great mobility and maneuverability which makes possible the rapid replacement and succession of theories and hypotheses. This theoretical fluidity is an indication not of the imperfection, but rather of the maturity of modern scientific thought, which is not content with the results achieved and tends to move forward quickly.

The development of thought proceeds along two interconnected paths. In the first place, on the basis of the generalization of the results of knowledge and experimental data, there takes place the formation of new concepts and theories. This is the general line of development in scientific thought, whose purpose is the discovery of the laws of the objective world. In the second place, thought is seeking to understand ever more deeply the laws governing its own progression, in order to make use of this knowledge for its own advancement.

One of the ways in which thought comes to know itself is the study of the methods and means of formalizing knowledge already attained, the application of logical formalism to various areas of knowledge, the investigation of possibilities for the solution of solving problems which confront thought by means of formal techniques, and the creation of algorithms to be incorporated in computers.

This second line of development in scientific thought emerges rather independently, but is nevertheless subject in the final analysis to the first and is dependent upon it. Thus, the formalization of scientific knowledge affords a possibility of solving individual problems formally by transferring to a machine a number of the functions performed in the thought process; this accelerates the rate of thought advancement and promotes the attainment of new results. On the other hand, the appearance of new concepts and theories in science creates the possibility for further progress in the formalization of formerly obtained knowledge, and in the creation of algorithms: the progress of scientific knowledge leads to an extension of the possibilities of formalization; man is solving an ever greater number of problems with the aid of machines. Any attempt made at this time to decide a priori in what fields it will be possible to employ computers for the solution of problems confronting thought cannot lead to any positive results, in so far as "machine thought" will, as science and technology are advanced, be applied to more and more fields where knowledge has formerly not been formalized to a sufficient extent.

"Machine thought" has unlimited possibilities, not as an independent mode isolated from its human counterpart, however, but rather as one of its subsidiary aspects. "Thinking machines" will leave their imprint on the most diverse spheres of our spiritual activity; their further development is one of the salient characteristics of modern scientific thought. But no matter how "clever", computers will remain simply a material means in the theoretical activity of man. Man will confer on the machine an ever greater number of functions performed during the thought process, reserving to himself the most important function of all--that of thought itself as a form of spiritual industry, the creation of scientific concepts, theories, and ideas which reflect the laws of the objective world.