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Organon 5, 41-48

1968

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LOGIC AND HISTORY OF SCIENCE

The significance of the history of science has of late increased considerably owing to new phenomena in science, especially to the immense increase in its rate of development, which has led to extraordinary complications in "scientific management". And this situation has set a task of extreme importance: that of disclosing the regularities of scientific development and of transformations of the structure of scientific development in the course of the history of science.

This task can be solved exclusively on a historico-scientific basis by way of revealing the interconnections between the crucial moments in the evolution of science and disclosing the mechanism of the logical situations, transition within science; essentially this leads to a logical generalization of the history of science.

Thus, in our view to reveal the regularities of scientific development is to establish the logic of scientific development. The development of science is an indivisible process of at least three "dimensions"; evolution of science as a system of knowledge (this "dimension" of science is characterized by maximum dynamism and in this respect it considerably excels the dynamism of other branches of human activity), its logical structure and, finally, its "dimension" as a social institution, as a definite means of activity. The last "dimension" of science comprises the system of the relations of science to other forms and fields of human activites (its "exteral" aspect) and its "internal" aspect consisting of such elements as forms of organization of science, types of human relations in science *etc.;* their study is a prerogative of the science of science or of the sociology of science.

The concept of the internal logic of science comprises the development of its ideological content, of its subject aspect of its logical structure, *i. e.* types of bonds between such components of science as hypothesis, method, theory, and experiment; the mentioned components are inseparably linked together.

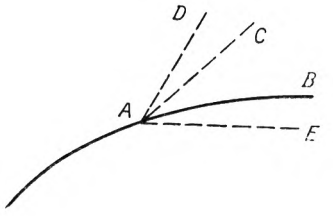
As a rule, by the internal logic of the development of science the following complex of its "properties" are understood: *1*) that the development of science is an autonomous process, in which the affiliation of ideas is fundamental, *2)* that science functions as a self-registering system, and *3*) consequently, that the immanent regularities clearly dominate over the impulses of development which science receives from outside. The acknowledgement of science as an autonomous system does not preclude the acknowledgement of the immense influence which science exerts upon the formation of the general structure of thought and upon the development of technology.

The problem of the relation between the internal impulses of development and the external influences in science is one of the important facets of the problem of regularities.

To deny the role of the internal logic in the development of science is as incorrect as to ignore the significance of the "influence" of external factors upon this process.

The "action" of the internal logic of scientific development is as follows:

1) The development of ideological-content aspect of science, including both the evolutionary and the revolutionary periods in the history of science, is determined by the past history, especially by the logical situation of its immediate period. Considering the first two "dimensions" of science, *i. e.* the system of knowledge and the logical structure, we thus establish the unique trend rather than the principle of many possibilities, operating in the development of science. The situation can



be illustrated correspondingly: on a complex curve of the development of science point *A* represents the situation characterized by Kuhn as the crisis of the old paradigm which has lost the ability to assimilate new facts and produce new scientific results; in result, science has entered a revolutionary phase of its development, which, in addition, is characterized by the uprise of conceptual activity, acquiring a diveregent character at the given stage (see Fig. 1).

Another problem arises here: whether the development of science could have taken the paths *AC,* or *AD* etc. (Actually it developed along *AB* as it is shown by retrospective analysis.)

A reconaissance of various paths is carried out during the characterized period; that results partly in the elaboration of concepts to be overcome comparatively soon in the course of the further development of science.

Generally, all theoretical works done within a transition period in the development of science can be divided into three groups: works being futile attempts to adopt the old paradigm to a new logical situation arising in science; studies aiming at new concepts generally inadequate in their treatment of the "burning" problems at this stage of the history of science: finally, studies elaborating a new and adequate paradigm. As an example of the second group, we may cite the energetics of Ostwald in which attempts are made to overcome the limitations of the mechanistic outlook in science ("solve everything in mechanics", to quote from Helmholtz); however, the results did not correspond to the intentions.

Retrospective analyses of the development of science always indicate that the direction along which science has been developing is the only possible direction of its movement, determined by the whole of its previous history. Naturally, that does not signify that extreme possibilities of science are fully realized at each stage of the history, and that further achievements were not possible in conditions of the fundamental ideas and experimental techniques then existing. But the sequence of the system of ideas and their development is a regular process; accidents are important to the extent that the ways along which scientists arrive at accidental results are "inscrutable"; however, their occurrence has the feature of inevitability in it which can be fully revealed by an analysis of the respective scientific events and phenomena.

2) Hence it follows that each period in the development of science contains a "vector" of its further development.

3) Further, the concept of the internal logic comprises notions of the occurence (and active functioning) of internal impulses in the development of science.

4) Contradictions inherent to science constitute these impulses of development; firstly, the "general", all-embracing contradiction, to be eliminated but still irremovable, reviving like Phoenix from the ruins— the contradiction between science as an open system and the relatively closed nature of scientific theories representing a strict system of notions. The consideration of the internal logic of science as a factor of great significance to its development, as a factor determining the movement of its ideological aspect and logical structure does not in this sense signify an adherence to the views on science as a self-regulating system and on its evolution qualifications as an autonomous process.

The development of science exhibits also a social logic, which is determined by its connections with other social institutions; that deter-

mines to some degree the "climate" in which science exists and the numerous consequences.

The impact of the social logic on the development process of science manifests itself in its influence on the following aspects: *a)* the rate of its development, *b)* the determination of the themes of science (setting up tasks with uneven possibilities of solutions and possible to be employed in practice); *c)* the determination of the type of connections between science and other social institutions. The action of "social logic" is mediated by the internal logic of science which passes through it, "urges" it and finally gets converted into it. The view which ascribes the development process of science solely to its constant stimulation with socio-economic factors and underrates the great action of the internal logic is one-sided and therefore erroneous.

The internal logic of science and the social logic of its development do not occur together and are not external to each other; they are definitely connected. What is the "other side" of interaction between science and society, which acts as the influence of society on the development of science? This aspect of interaction is related to the nature of science as a social institution; the principal function of the latter is to generate systems of knowledge and certain types of ideas and to obtain certain solutions from a definite moment in the history of science. The value of that function increases and is converted into a necessary condition for the reproduction of all fields of social activity; science increasingly expands into all "pores" of social life and turns into the most important field of activity.

The problem of regularities in the development of science includes primarily the problem of the relations between the logical and the historical. The first aspect of the latter problem is that the logical appears as the cognition of the essence of the historical, *i. e.* it unfolds the principles of its development, the regularities of its movement.

The cognition of the actual historical advance in the development of science involves its logical generalization, *e. g.*, in the elaboration of the universal and necessary moments of this advance, in the elucidation of its actual occurrence and of its motive powers.

To reveal the logic of science movement is to unfold the features of generality and necessity, which determine the movement of the flow of science and represent its central lines.

If history reveals the picture of the process in its whole diversity and richness of concrete forms of the development, logic clarifies the determinant of this process and its necessity; it further shows the transformation of the results of the process into the obligatory condition of its further development.

Thus, the logical constitutes the main line of the flow of development in scientific thought, which consists of many units; every last unit

possessing the whole power of the previous development and determining the successive development.

"Extending" this line means, essentially, a characterizing of the dominant of the development process in science, liberated from zigzags and fluctuations. From this point of view, the logical appears as the historical rectified; it represents a generalization of the latter (not in the sense of revealing the most general traits, inherent to diverse historical phenomena but in the sense of establishing the laws of their movement).

The conception of the logical as the historical rectified, as its axis in which all the elements are necessarily connected "following" from one another was advanced by Marxist classics. Engels pointed out that the only appropriate method was logical consideration. Essentially, this method was nothing but the historical method; however, it was liberated from its historical form and in accidence. (See:: F. Engels' article in K. Marx's book *Zur Kritik der politischen Ökonomie.*) "At first sight this form has a great advantage of greater clarity, since real development is observed there; however, such a form could actually be at best only popular. History often takes recourse to jumps and zigzags, and if we follow its course in the reverse order, then—and owing to that—not only attention could be paid to material of much lesser importance but also the chain of thought would have to be very often broken." [1]

The problem of the relations between the logical and the historical has another aspect: the relation between the role played by some scientific category in the history of science and its significance and place in a certain scientific system formed after the birth of this category. The question was thus answered by K. Marx: "thus, it is inaccessible and erroneous to consider the economic categories in that sequence, in which they historically played decisive roles. On the other hand, their sequence is determined by the relation in which they stand to each other in modern bourgeois society, and this relation is in contradiction to what seems natural or corresponding to the sequence of historical development." [2]

The role of an individual scientific category in the system is naturally determined not by its significance in the past, but by the character of the given system, by its totality, the law of its movement which consists in the successful development of its possibilities and inherent potentialities. The movement of a scientific system, as a rule, takes the direction of elaboration of a more closed circuit as compared with the initial stages of this process, and that leads to an "explosion" of the contradiction between this system and science as an open system.

[1] K. Marx and F. Engels, *Selected Works in Two Volumes*, Moskva 1948, pp. 332 (Russian edn.).

[2] K. Marx, *Zur Kritik der politischen Ökonomie*, Moskva 1949, p. 221 (Russian edn.).

A determination of the given system in the chain of scientific development naturally presupposes the relation between its most mature form, corresponding to the stage at which it "realizes" all its potentialities and liberates itself from "relics" and the whole of the previous and successive stages in the development of science.

The logical method interpreted as a "corrective" to the historical research makes possible the investigation of the subject in its most mature form.

The subject is, Engels wrote, not the logical process solely, but the historical process, its reflection in thought and its interpretation, logically tracing its internal connections. [3]

Another aspect of the problem of the historical and the logical is the problem of the relation between phylogeny and ontogenesis of human cognition. Moreover, the latter problem has at least two aspects: "educational" and "scientific". Previous to the advent of Marxist philosophy the problem was set by Hegel and solved with a method containing the consistent principles of historism.

An individual, Hegel wrote, should in content pass the stages of the education of the mind; however, these are forms left by the mind, a well-developed, equalized path; thus, in regard of cognitions, we see that what at earlier stages occupied the mature mind of men is reduced to cognitions, exercises and even puerile plays, and the advance of teaching enables us to recognize in a concise form the history of the whole world enlightenment. [4]

Thus, from this point of view, the history of the moral development of moulding the individual also reproduces the moral development of all mankind. In his moral evolution a young man must necessarily repeat all the stages passed for long by mankind.

The concept of the given type of relations between ontogenesis and phylogeny received further development in the so-called second biogenetic law. Up to the present epoch, this is among the main problems faced by the pedagogical science. However, we are interested in a different aspect of the problem of the relation between phylogeny and ontogenesis, in other words—in the revealing of phylogeny, its concentrated and pure reproduction within the ontogenetic movement of knowledge.

Essentially Hegel speaks of this aspect when saying: "... science reproduces this educational movement in all its completeness and necessity." [5]

The ontogenetic movement of knowledge reflects the phylogeny of

[3] F. Engels, *Supplement* to the third volume of *Das Kapital*: cf. K. Marx, *Das Kapital*, vol. III, p. 908 (Russian edn.).
[4] K. Hegel, *The Phenomenology of Mind*, p. 15 (Russian edn.).
[5] *Ibid.*, p. 15.

knowledge; it passes through a number of essential points in phylogenetic development, the latter being points of issue for ontogenetic development.

A study in any field of science with a history (in that this is not a newly discovered fragment of reality) reproduces history and repeats its most essential stages.

Let us consider, for example, the kinetics of chemical reactions. Studies in this field pass the mutually connected stages, *mutatis mutandis,* which repeat definite stages of its history. Thus the starting point of these researches is the study of the phenomenology of reactions, that is, the determination of the stechiometric reactions and the dependence of the reaction rate on the concentration of reacting substances. This stage of study corresponds to the first stage in the development of chemical kinetics, when the latter was engaged in establishing the mentioned dependence and developing criteria for a kinetic classification of the reaction.

The second object of the study is to establish temperature dependence on the reaction rate, which is an interesting problem in itself, but principally serves as a means to determine the main dynamical parameter of the reacting system—the energy of activation.

The next stage is the study of the reaction mechanism, *i. e.* revealing the elementary reactions which in their totality postulate the given chemical transformation, and the identification as well as the determination of parameters of intermediate particles (radicals, atoms, ions *etc.*). The entire research which aims to determine the rate and mechanism of reactions in their inseparable links, included all the stages which we have enumerated above. Thus, the entire cycle of study in the kinetics of reactions—from phenomenology to the detailed study of its mechanisms by various methods of modern science—repeats the most essential stages of the development of chemical kinetics, *i. e.* ontogenesis is necessarily reproducing the most essential and fundamental in phylogeny of the given branch of science.

A similar relation between ontogenesis and phylogeny exists in other branches of chemistry, *e. g.* in organic chemistry. The studies in organic compounds start with the determination of their elementary composition, which at the early stages of organic chemistry was the acme of study, and served as the most powerful tool in the cognition of organic compounds. Determination of functional groups and radicals of this group corresponding in "ideal" relation to the last stages of prestructural chemistry, though considerably more effective and safe owing to modern techniques, follows as the next stage.

The next problem to be solved is that of establishing the structure of this compound, *i. e.* the determination of the type of bonds between atoms in its molecule with the help of classical organic chemistry by

means of destructuralization of the given molecule and identification of the fragments.

The investigation is closed when the determination of the molecular geometry is achieved, *i. e.* the interatomic distances, valent angles *etc.* are established. In this way, the whole history of organic chemistry with all its essential features is inherent in these studies.

Thus we have generally examined all the aspects of the problem of relations between the logical and the historical in the development of scientific knowledge: *1*) the logical as the historical "rectified"; *2*) the logical as the highest form in the development of a given method to cognize the corresponding fragment of reality and *3*) the logic of the reproduction of the phylogenetic process by ontogenetic development.