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THE RELATIONS BETWEEN LOGIC, EPISTEMOLOGY AND METHODOLOGY

By the term methodology I denote the basic ideas or general principles derived from different individual sciences and expressed in an abstract and general language. Methodology must be distinguished from scientific methodics. Whilst methodics concerns the fundamental working methods of individual sciences, methodology deals with the scientific and logical connection between facts, terms, hypotheses and laws in the sciences. Because this connection exhibits general and formal structural laws and, thereby, takes on the form of a logical system, there are no limitations concerning the possibilities of application in concrete disciplines. The forms or structures investigated by logic represent that system of relationships which is valid for all possible subjects and which claims to be scientific. Its elements or operations are common to all sciences. The logical penetration of the fundamentals of a scientific system is a premiss indispensable for the philosophical evaluation of a theory. Thus, the necessity of taking into consideration scientific-logical questions is greater or lesser depending on the special discipline involved, above all, on the degree and therewith the level of abstraction of the particular science. It becomes increasingly obvious that modern logic assumes a central position within the methodology of sciences. It will hardly be disputed that modern logic has great possibilities of application both in fundamental research and in the applied sciences. Modern logic differs from classical logic by its formalization, calculization as well as, in general, by its symbolization and axiomatization. In contrast to traditional logic, it distinguished itself not only by a higher formal strictness but also by a greater richness of content. Modern logic makes possible the analysis of an abundance of problems and the derivation of countless laws which are foreign to traditional logic [1].

[1] Albert Menne, *What Is and What Can Logistics Do?*, Paderborn 1967.

The possibilities of application of modern logic can be roughly grouped in the following way:

1. The construction of the axiomatic-deductive systems:

Mathematics
Physics
Philosophy

Here we are concerned with the proof of freedom of contradiction and the completeness of such systems.

2. Language analysis, language critique, and the analysis of meaning within a given language, as well as the comparative syntax of more languages or even general syntax and semantics.

3. Logical analysis and fundamental terms and the basic premisses of the individual sciences (= fundamental research).

4. Practical application in the modern programmed calculating machines.

There is a connection between these facts and the increasing attention which has recently been paid to questions of formal language and scientific theory both in the natural and social sciences and in technology. This is due to the increasing importance of abstraction, of mathematical methods and of scientific symbols in the modern natural sciences.

The progressing formalization of scientific perception among scientists, logicians and epistemologists has led to serious discussions concerning the nature and character of language. A considerable number of these discussions deals with the relationship between natural and artificial languages. Doubtlessly, the increasing process of formalization in the sciences belongs to the regular phenomena, according to natural law, in the development of modern science. Subjectively, these phenomena are expressed in the development and perfection of thought which increasingly deals with the objective laws of nature and society. It is based on abstractions such as true theoretical generalizations of facts which have been gained from experience.

Questions such as these of the role of logic in scientific perception, of the transition of scientific hypotheses to scientific theories, of the formation of concepts in the individual scientific disciplines, of the scientific possibility of proof of this or that theory, are problems which present themselves to all scientists in their work. They are of a directly philosophical nature and they have to be answered by the philosophers who are investigating the relation between formal logic and scientific theory.

Scientific perception is based on observations, experiments and generalizations. For the applicable methods attained in the individual

sciences—such as the method of formalization, and axiomatic and genetic methods—are contained in the fundamental of formal logic.

These methods contain not only formal-logical aspects but also gnoseological aspects. Although each of these aspects can be seen from the standpoint of independent disciplines—formal logic, semiotics and epistemology—theoretical investigations are concerned with the interconnection rather than with the independence of these disciplines. Thus, the fundamental logical questions, such as statements and predicate calculus, analysis and synthesis, reduction and deduction, questions of the hypotheses and formation of theory as well as proof, belong to the integrated constituents of each science. Also, the problems of the formation of terms (nominal definition, analysis of meaning, explication) are of particularly great practical importance to the individual sciences. Spontaneous logical thinking no longer suffices to solve the complicated methodological problems in some specialised fields. The full understanding of questions of dialectical materialism presupposes a serious study of logic. This by no means contradicts the fact that the fundamental theoretical questions of logic have their methodological basis in dialectical materialism. The construction of the calculus of logic itself requires no philosophical fundamentals. Metalogic deals with the philosophical fundamentals of the calculus of logic, *i.e.* with the epistemology and problems of ontology.

Metalogic has to start with metalogical problems, that is, with the formal assumptions of the calculus of logic, with semiotics as the theory of formalized language. This includes syntax which deals with the rules of formalized language, semantics which studies the signs of the language in their relationships to what they describe, and, finally, pragmatics which investigates the signs in relation to the subject which it constructs and uses. Metatheoretical questions, which today play an increasing role not only in mathematics (Hilbert) but also in other disciplines, have so far been investigated to a small extent only. Today they are still frequently underestimated as „subjects which are estranged from practice". However, we must carefully evalute the results obtained (Frege, Tarski, Scholz, Hermes, Carnap, Kleene and others) and consider metatheoretical problems in further investigations. The distinction, originating from Frege, between sense and meaning is of great importance to semantics. In a statement "sense" is its content, meaning is its value, *i.e.* its "true" or "false" quality.

Moreover, the needs of social practice today demand an increasing consideration of logical and scientific-theoretical questions. It is known that the development of "machine" thinking, which economically has a great perspective (automation and mechanization of production, effective provision of collected knowledge, *etc.*), puts up many new and difficult problems.

Questions of logic are today inseparably connected with philosophical as well as technical problems. Logic has become a decisive factor in the development of the forces of production and production as such through its application in technologies. Mathematics and quantum mechanics, electrical engineering and the theory of electronic calculating machines, research into the neurophysiological processes, as well as cybernetics itself—all these constitute the field of a creative application of the laws and methods of modern logic. Apart from its application in technology, in mathematical linguistics and in medicine, logic is also applied in the analysis of the logical structure of our process of perception, in the analysis of the formal elements in the process of perception, as well as in the analysis of the development of the inner structural laws of scientific perception concerning the most important theoretical problems of fundamental research in the field of logic. In this connection, of special importance is the working out of the logical problems of modern scientific language. The relationship between word and term (concept), sentence and statement, as well as the problems of semantics and logic are of special importance. Thus, in his book *The Vienna Circle* (New York 1953) Viktor Kraft writes that logic and mathematics have nothing to say about the perceptible reality from experience. Logic contains no perception, it does not give the fundamental laws of existence nor the fundamentals of the order of thinking. Logical relationships are only relationships of thought, they do not exist as actual relationships within the system of representation. Classes, for instance, are nothing real but a summary of thought. And negation in the environment does not correspond to its own "facts of the case" besides the positive one. Because logical relationships are purely formal they can be established quite independently from the special sense of the propositions, from the concrete facts of the case. Therefore, they cannot express anything concerning Being. Logic contains the fundamental laws of order within the symbolic representation. In thoughts formalised by language, objects and relationships are given symbols and symbol connections. This correlation does not only have one meaning, so that each object corresponds to each connection and *vice versa,* but it has more than one meaning so that more than one symbol and symbolcomplex correspond to the same object, though not the other way round. Therefore, it is possible to convert into one another from the symbol-complexes which describe the same object or "fact of the case". The rules for such conversion form the content of logic. As pure logic, it lays down only the laws within the symbolic system, not the laws of the world as perceived. The well-known logical statement "What is valid for all is also valid for each individual one" is the same "fact of the case" by two different symbolizations, namely, by "all" and by "each individual one". But it

is not a characteristic of the world that what is valid for all is also valid for each individual one.

Also in the treatment of logical problems within the framework of his *Erkenntnislehre* (Vienna 1960) Viktor Kraft took this conventional point of view in the proof of the laws of logic. According to him, the reason for the general validity of logic lies neither in that there are laws of reality which find their most general formation in logic nor in that there are original general forms of function of the "spirit" of the thinking consciousness, but in that the rules of logic are necessary stipulations. They are necessary because they standardize rules of practice, which is the condition of unequivocality and order of thinking. The necessity of statements on logical relationship is supposed to rest on the rules of the procedure of order. According to the rule of order something can only be so and nothing else. By this the opposite is excluded. If logic is valid for all possible worlds and for all realities, it is only so because it is valid for the thinking order of all realities, and not because it reflects their ontological structures.

According to V. Kraft, logic contains no ontological laws or natural laws of existence or thinking, but formal relationships without descriptive content. Therefore, logic has nothing to say about reality. Logic consists of pure relationships of thought. These are produced by logical constants and operations and by variables, whereby the descriptive relationships are represented. In this way, logic is "formal".

The rules of procedure are established by logic, that of the order of thinking, according to the stipulations for logical constants and operations and according to the demand of identity and the exclusion of contradictions. Logical deduction is based on this. Logical truth is based on rules of order, logical falsity on their neglect. Logic has general validity because it is based on the rules of order.[2]

Although V. Kraft defended in principle this conventionalistic standpoint in questions of logic and also of mathematics already in his work *Mathematics, Logic and Experience* (Vienna 1947), traces of a relationship between mathematics, logic and reality can here, however, be domonstrated. He poses here the basic question, *i.e.* the question of the relationship between logic and reality, and concludes that a logical conclusion is valid for reality because it contains rules (laws). It can be applied in so far as the formal logical relationship of the general and the particular in reality contain a determination and fulfilment of content. Thus, only by the rules of thinking can we arrive at a conclusion which agrees with reality, without worrying further about reality, according to which we change over from a given statement on "all" to a statement on an individual one. It is the rules of nature

[2] V. Kraft, *Doctrine of Cognition*, Vienna 1960, pp. 148, 153.

themselves to which the laws of deduction correspond. In this work, Kraft is led very close to a realistic epistemology by his attitude against conventionalism which is founded on reliable arguments. However, this standpoint is not carried through to its ultimate end. Any misinterpretation of logic is excluded, though, if logic is united with philosophy of science. Formal logic then constitutes only a special and elementary part within the theory of science.

Lorenzen also speaks about a general logic which includes formal logic. General logic is the theory of the foundations of science. In this part of logic the term science must be discussed. A science is defined as a system of propositions which stand in fundamental connection with each other. The system must be well ordered in the sense that by the foundation of propositions by other propositions and then by the foundation of this proposition etc., one never gets into an infinite regress, especially into a circle. [3] Therefore, general logic is characterized by Lorenzen—and here we can only agree—as a philosophical discipline. Formal logic as a special though simultaneously indispensable part of philosophy, without its own agency, receives now a special part "from the mathematicians delivered free in a practically perfect shape". What will philosophers do with this present? Many philosophers exhibit much reserve towards this mathematical gift. The packing in such unusual symbols mostly disturbs them. But as this represents no theoretical difficulty, persuasion will already be of help. The basis for accepting this present should indeed be that no demand will be made that logic should take over metamathematics and recognize it as logics. Some mathematicians have become today "would-like-to-be" philosophers and offer logic not only the modern formal logic but equally, *e.g.* another ontology, a language philosophy or even a critique of reason, as though everything has been proved mathematically.

Here I should like to recommend urgently the thankful acceptance of formal logic from the mathematicians but the polite though decided rejection of anything else. The mathematicians are only responsible for formulas. Each proposition, in which any kind of word of philosophical tradition occurs, however harmless it appears, must be taken over by philosophy as its own responsibility [4].

Modern formal logic is thus an essential constituent of scientific theory. In the system of methodology of sciences, the task devolves upon modern formal logic to ensure freedom of contradiction of statements and to furnish the basis for a language of science. It functions as a mediator between philosophy and the individual sciences. Logic takes on a direct methodological character as the basis of the semiotic method of the explication of terms. Terms obtain a real meaning when

[3] P. Lorenzen, *Collegium Logicum*, Erlangen 1963, p. 10.
[4] *Ibid.*, p. 15.

they reflect facts. The term is marked by that it contains the logical invariance of one of the elements of reality. The realm of validity of this invariance includes all possible transformation or all possible objects. During the gaining of perception the system of terms of a science changes. In general, the precisioning and enlargening of the system of terms occurs. Inadequate terms are here eliminated. An exact verification of terms is made possible by the method of explication of terms, (analysis of meaning), which allows us to check exactly whether we are concerned with an everyday term, a scientific term or with an empty group. R. Carnap has already formulated the essential elements of the methods of explication of terms. He distinguished between the *Explicandum,* that is vague meaning of words of everyday, and the *Explicatum,* that is the exact term. The *Explicatum* must fulfil the following four requirements:

1. Similarity with the *Explicandum* (no complete agreement).

2. Fertility of the terms applied: brought in connection with other terms and as a basis of the statements of laws.

3. The most feasible accuracy. Formation in a system with closely connected scientific terms.

4. Postulate of simplicity.

a) Simplicity of the term-definition.

b) Simplicity of this term made possible by the law of statements.

The explicated term itself occurs in three forms:

1. Classificatory form (classification of things into two or more classes which exclude each other, as it is with the classification of plants and animals).

2. Quantitative form, *i.e.* objects or properties are characterized by means of numerical values (length, duration of time, temperature, income, export quota).

3. The most feasible accuracy. Formation in a system with closely income, export quota).

However, the application of Carnap's method of the explication of terms has been heavily impaired by its subjective idealism in questions of epistemology. Therefore, it is necessary to develop the method of the explication of terms on the basis of a scientific epistemology, that is, on that of dialectical materialism. We arrive at an accurate method of the examination of our equipment of terms. The explication of terms can be described in the following way:

Explicandum	*1. Designatum*	*Explicatum* (*Explicans, Explicat*)
(vague meaning)	*Denotatum* Empty class *	

Designatum: Class of the named object (Name) Figures (semantic aspect)	2. In case of ambiguity: notation of meaning
Denotatum: Language signs and function of relationship Naming of objects (elements), characteristics or relation to reality	3. Exact rules for the use of the expression: putting the term into a system of scientific terms.

* Name (*designatum*) without real *denotatum*.

The explication of terms contributes essentially to the elimination of the inadequation of everyday language and to the construction of a scientific language. The fact that the inadequacies of everyday language have led to the formation of special scientific languages cannot be disputed. Each scientific discipline must today cultivate its own scientific language adapted to its own specific characteristics. Herein rests already an essential part of the work to be done. The point of view that the introduction of special terminology is more or less strange to the natural language or it is dispensable or even harmful, fully misinterprets the situation. The effort in the formation of a scientific language must be towards the achievement of a complete clarity of sense. Only the gradual replacement of indeterminate expressions of everyday language by more accurate ones makes possible the solution of the problem which is first posed by language and then by science—the problem of an adequate description of the environment. An adequate description of the environment is identical with the perception of reality. Any perception must express itself in signs and words. Therefore a knowledge of the connection between language and logic is fairly important for the acquisition of perception. This includes a thorough investigation of the signs and words in connection with their functions of meaning. By investigation of these connections themselves the relation between natural and artificial, that is, a further clarification of the formalized language may be arrived at. It will then indeed be found that both are not at all fundamentally different.

CONCLUSIONS

1. During the acquisition of perception the systems of terms of a science change in many ways. In general it leads to a precisioning and enlargement of the system of terms. Here inaccurate terms are eliminated. A verification of terms is made possible by the methods of the explication of terms.

2. Logical conclusions are valid for reality because they are made up of rules and laws insofar that the formal logical relationship between the general and the particular find real determination of content and fullfilment in reality. That is why we can only come to a conclusion which agrees with reality through the rules of thinking according to which we change from a given statement on "all" to a statement on an individual thing without worrying about reality.

3. Logic is already contained in language; language has already been formed by it. However, everyday language is not sufficient in all cases in order to make a conclusion in a correct logical way. Here logical grammar helps us further. The conditions for the application of language are, therefore, also only a part of the conditions of the application of logic.

4. Logical conclusions guarantee only the correctness, that is, the norm of the deduction of a concluding proposition, but not its truth. This is dependent on the reality of the premisses. Truth is a matter of its own and logical relationships form its structure. The formula: "the proposition p implies the proposition q, p is valid, therefore, q is valid," belongs to logic, also when the independent assertion of p and q is no longer a matter of logic, because they are statements from the standpoint of truth.

5. Laws, rules of conclusion, etc. which have been investigated by formal logic are an integrated part of the general methodology of the sciences. Formal logic is indispensable to the construction of scientific theories, to the procedure of the acquisition of scientific statements in the different disciplines and to the examination of the structure of theories.

6. The methodology of sciences as well as scientific theories cannot be reduced to mathematical logic, although the terms and the apparatus of mathematics and logic form an essential basis for methodological-scientific theoretical operations. Without considering the fundamentals of mathematical logic, the further development of a number of sciences is no longer possible by today's standards. Mathematical logic helps us in the examination of the bases of assertions, in the explication of terms which at times plays a special role as in the elimination of logical contradictions.