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THE SCIENTIFIC REPRESENTATION OF REALITY: ITS DIFFICULTIES *

1. Material reality, constantly variable and constantly in movement, dialectic in its nature, is reflected in the sciences which at specific stages of their development possess an *univocal* form: the results of knowledge are expressed in a language which uses terminology and symbolism, its ideas and its statements have a precise and definite sense.

In this respect two important gnosticological problems appear:

(*a*) What are the logical processes for representing "variable" and "indefinite" reality (as Engels suggests, strict lines of demarcation between objects do not exist there) which we use in the process of knowledge and which enable us to create a scientific image of the world possessing at each stage a certain "raw truth", constructivity and a certain univocal nature.

Translated by Paul Grigorieff.

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(*b*) Does not scientific knowledge in this case deform the true position of objects?[1]

We shall restrict ourselves to the examination of the former problem.

In order to resolve it, we shall take as a basis a well known position put forward by Lenin in his *Philosophical Notebook*. Lenin wrote: "We cannot realize, express, represent movements without interrupting the 'continuous,' without simplifying, vulgarizing, dividing, insensibilizing the living matter. The representation—and not only thought but by the sensation of all movement and all knowledge. It is in this that lies the fundamental principle of dialectic expressed by the formula: unity, identity of contrasts."[2]

We will formulate as follows the theme dealt with in this article:

We know that there exists in the world not only movement (modification), but also "rest" (in the sense of the relatively precise qualitative definition of objects, or in the sense of relative *invariance* of the modifications themselves of the objects and of the reciprocal actions). Thus we can bring out clearly this invariable and "raw" substance of objects and abstract it in a certain "pure" form. In carrying out this abstraction we call upon the processes of idealization and carrying to the absolute, upon a "halting" of the movement, upon "insensibilizations" and "vulgarizations," the transformation of the continuous into discontinuous (discrete), identification of models and the original, identification of the approximate and the precise, the reduction of the complex to the simple (which is called simple in a certain absolute and atomic sense of the word)[3]; we establish quite "rough" rules of identification etc... Thus, reality in the process of knowledge appears in a simplified, "vulgarized" form. This creates enormous advantages for the knowledge and trasformation

[1] It is known that similar problems in connection with difficulties of identification of the object with itself have already been formulated, for the first time, in the history of West-Europe philosophy by Heraclitus of Ephesus.

[2] Lenin, Vol. 38, page 255.

[3] Here, we will examine the so-called traditional method of representing reality. We will not touch upon "not-classical" methods of this representation, in terms of cybernetical processes for modeling complicated dynamical systems.

of reality on scientific bases. It is only by these means that we are able to formulate general laws, to describe them in mathematical language, to use them as a basis for forecasts, to replace direct experimental research by calculations (on the basis of very limited information obtained from a combination of experiment and measurement) and to formulate sufficiently simple rules of operation for the objects under study (e.g. formulate quite simple general rules concerning a virtually infinite number of analogous situations and contexts). This means that the simplification of reality represents a means of knowing it more profoundly. But the simplification, the idealization and the carrying to the absolute of which we make use at each stage of development of science are only provisional. When the flagrant contradiction which exists between them and the domain of reality under study is discovered, they must necessarily be modified (reject them, replace them by others, or define them with greater precision).

Thus we use dialectic methodology in the process of scientific knowledge or reality:

(*a*) when we carry out the process of visualizing it by contrasts: we conceive the continuous from the "discrete," the individual from the general, the concrete from the abstract, the whole number from its component parts etc....

(*b*) when we distinguish a scientific image (created by ourselves) from a fragment of reality on the basis of the discovery of the contradiction between it and the objects under study.

The situations dealt with above will be illustrated in concrete form later.

II. At the empirical level of knowledge we have already a series of simplifications of the situations studied.

We know that a unit of measurement, whatever it may be, is approximate in nature. On submitting the results of a measurement obtained during an experiment to mathematical study we admit new vulgarizations. Thus we find ourselves faced with such cases when setting up a table of functions. As is well known, here the method for smoothing the data inscribed in the table plays an essential role. There exists a whole series of methods for such a smoothing of data. One of them is graphic. It consists of drawing the graph corresponding to the data in the table, which expresses the relations between X and Y. Within a given system of coordinates, points are marked in corresponding to the values of X and Y shown in the table, then a straight line or smooth curve is drawn. It does not necessarily pass through all the points shown in the graph. It is constructed in such a way, that the data in the table are smoothed; it may also pass close to certain points marked in. In this case the method of approximations is often used. The values of Y on such a curve (together with the values of X for which a "non-smoothed" table is constructed) are shown in a new column of the table called a "smoothed" table.

The analysis of the corresponding tables and graphs often obliges us to suppose that between X and Y there exists a constant and definite quantitative relationship which it would be desirable to express in the form of an equation. The process of obtaining such equations and their coefficients sometimes presents a complex problem. This problem consists in the fact that the formula should be capable of reflecting all the experimental data, should at the same time as be simple as possible, and should not contain a large number of specially selected constants. There is no one method of selecting the best formula, but there are a number of processes of considerable heuristic importance for reaching such a selection. Thus every researcher has available to him a large number of graphs corresponding to the most varied equations. By comparing the graph obtained from the table with the graphs already in existence, it is possible to make a more or less appropriate choice of equations, to modify it later, and to improve its accuracy by applying it to the problem under consideration. (We shall ignore the difficulties relative to the problem of interpretation of the equations chosen). It should be noted that the transition from empirical mathematical description is always linked with the transformation of the conceptual and semiological apparatus in the sense that we identify variables with general notions of concrete content and their values are no longer represented by concrete objects with properties which can be perceived with the senses (as is the case when using general notions at the level of the qualitative description of reality) but by idealized abstract objects (figures, points, characterized by two or three figures etc...).

III. No scientific theory (in any case the theories of natural science, not to mention logico-mathematical theories) can be constructed without the introduction of corresponding idealizing hypotheses and of idealized objects.

We encounter such hypotheses when a certain problem which we cannot solve with the aid of experiments is accepted by us as solved on the basis that it can be (at least partially) on certain conditions.

Thus the abstraction of the infinity of reality widely used in classical mathematics is based on the following hypothesis: we can count the whole natural series of figures (a problem which we cannot solve experimentally is accepted as being solved). The abstraction of the potential possibility of achieving this, which replaces the abstraction of the actual infinity in constructive mathematics, results from a less powerful hypothesis wich consists in the fact that it is possible to carry out a finite number of operations (paces, letters, figures)—the problem is considered as solved. This is why these abstractions are often considered as idealizations.

In practice the abstractions of the potential possibility of realization result from the hypothesis that the effective obtaining or construction of the infinitely large or infinitely small does not cause modifications of a paradoxical nature in the object obtained.

In his geometry, Euclid admitted that any fragment of a straight line (infinitely large or small) can be divided into two parts with the aid of a compass and ruler (such a problem was considered as being solved). Euclid incorporated this hypothesis in his theory as a basic assumption.[4]

It is possible to talk about the idealization process in the same way as that of the creation of specific idealized objects.

Let us show from the example of a notion such as "inertia"[5] how idealized objects are introduced into science. Let us suppose that we push a cart along a road; it rolls for a certain time and

[4] Talking of this, Euclid, in his *Principles*, had clearly formulated in the form of axioms of such situations, the situations without an obvious "attribute"; in order to accept them it would have been necessary to agree upon them from the beginning.

[5] The example has been taken from Einstein's and L. Infeld's work: *The Evolution of Physics*. Literary technical and theoretical Editions - 1956 - pages 42 & 43.

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then stops. There exists a series of means for lengthening the distance it will cover: greasing the wheels, improving the surface of the road etc... the more easily the wheels, turn and the smoother the surface, the longer the distance it will cover. Experiment shows that if external action upon a body diminishes (in the present case it is a question of friction) the distance covered by the body increases. In other words the distance covered by the body is inversely proportional to the external influences on the body in motion (friction).

We can discover more and more means of reducing these external influences and consequently new means for lengthening distance covered; it is however impossible to eliminate finally all the external influences (including friction). The regularity which we determine (the constant relationship between the external influences on the body in motion and the distance which it covers) enable us to conclude that if these influences which act upon the body could be completely eliminated the latter would continue to move regularly and in a straight line for an indefinite period (provided it was not at rest). Such a conclusion had been reached in his time by Galileo.

Similarly it is possible to imagine the introduction in physics of idealized objects such as "an absolutely solid body," "perfect darkness" "the perfect gas" etc.

This idealization is a mental process composed of the following stages:

1. By modifying certain conditions in which the object under study is situated we reduce their influence (sometimes we increase it proportionally).

2. We discover thus that certain properties of the object studied are modified in a constant manner.

3. By supposing that the influence of the conditions on the object are reduced to zero or that they have reached a certain "invariable level" we arrive mentally at a certain extreme case and consequently at a certain idealized object.

By means of this process of idealization we have the possibility of discussing idealized objects and their properties as objects having a real existence, although in reality, there exist only prototypes of these objects in the form of objects having a real existence and subject to certain definable rules. By creating such objects we form concepts concerning them, revealing their general and particular characteristics.

It is unliked that the characteristics of the idealization process set out above can be examined as a definition of this process in general. No doubt they are typical of a certain proportion (probably very large) of the idealization processes connected with the introduction of idealized objects into science, an introduction which can also be carried out is a somewhat different manner from that described.[6]

Sometimes the introduction of idealized objects is carried out by means of the following process: the action of conditions may be modified in totally different ways but its influence on the object under study is shown to be completely insignificant. By abstracting these influences in general, a certain idealized object is created, invariable in relation to its conditions. It is in this way that an idealized object is introduced in hydrodynamics: "the incompressible liquid." The process can be explained thus: as a result of the compression of the liquid, certain pressure forces appear. However, the compression of liquids and consequently the modification of their volume is very insignificant even at extremely high pressures. We can therefore abstract the pressure itself and the modifications in volume which appear in this case. It is in this way that the idealized object is introduced: "the incompressible liquid."

In this case, having established that all liquids possess a general distinctive characteristic (only insignificant modifications in their volume take place at different pressures i.e. after abstracting their identity) we reject this characteristic of liquids and proceed to study them as bodies of which the volume does not alter at different degrees of pressure. Here we have before us the moment of idealization, we create mentally an object which does not exist in objective reality, where there are only approximate prototypes. Similarly Joukovsky introduces in mechanics an idealized object "the material point," quoting ontological reasons in favour of the idealization given.

[6] For details concerning the process of idealization, see *Abstraction Problems and Formation of Concepts* by Gorsky, 1961. Ch. VIII.

"It is like a ball filled with material, of which the radius tends toward the infinitely small while its mass remains the same. Although this representation is purely fictitious since unlimited compression is in contradiction with the tightness of the material, there exist however in the mechanical sense of the words points having a significance identical to that of the material point of the final mass. In reality let us suppose that the body moves under the effect of a force applied to the centre of gravity. If we focus our attention only on the movement of the centre of gravity, we note that it does not depend on the density of the material or on the shape of the object but only on the quantity of material in the body. The centre of gravity moves as if the mass of the body were concentrated in that-point alone; thus we see in it a sort of realization in practice of the material point."[7]

Sometimes we speak of the idealized geometrical form of certain material formations, e.g. crystals, assuming an influence from external conditions tending toward zero.

In similar fashion by ignoring certain insignificant variations between the shape of bodies and the ideal (perfect) geometrical shapes, we call these bodies spheres, ellipsoids, cubes etc...

If on the other hand we try to project with any given degree of accuracy the outline of even the most "mathematical" material things which exist (the graduations on the ruler for example) we shall be convinced that this "mathematical nature" of the outline is only so at a certain degree of accuracy. By observing for example each fragment of the outline through a microscope we shall be convinced that the straight line is no longer so or that the sphere is no longer round; the more sensitive and precise the microscope, the more evident the divergences between the shape of the object and the so-called mathematical shape will become. The direction followed by the smallest of curves will prove to be made up of other curves following different directions and so on. The idealized mathematical image of such a coincidence of the absolutely true and exact outline of the object is nothing more than the curve composed of dots with no individual directions.

The extreme idealization of the "continuum," such as flat curves, seems more natural and corresponds better with the outlines

[7] Joukovsky, *Theoretical Mechanics* (State Technical Editions. 1952, p. 12).

of real objects or movements than do extreme resemblances. For example in the case of the idealization of the shape of the Earth, we accept a certain simplification, ignoring the unimportant divergences from the perfect geometrical model (exactly as we ignored the slight variations in the volume of liquides under pressure). On the other hand, in the case of a straight line (the points composing it having no direction) we create the idealization by basing ourselves upon its infinitely close approach to the characteristics of the physical world (relying of course upon the fact that we accept that the limits of physical objects are absolutely continuous).

The idealization process, as can be observed in the example already quoted, is linked with a considerable simplification of the subject under study. In the process of the creation of idealized objects, we ignore their aspects or relationships of minor importance, we eliminate the material prototype of the secondary, the eventual, the non characteristic and we present them as a certain extreme model, impossible to achieve in actual material reality.

This gives us the possibility of creating theories of a general nature reflecting the systems of the objects studied in terms of their constant, essential relationship, of reducing the number of parameters which it is indispensable to take into account to obtain a description equivalent to the objects studied, and of achieving an effective application of the apparatus of mathematics to the results of knowledge. The use of the idealization process in the realm of science reinforces its heuristic possibilities.

IV. There exist two types of contradictions: the formal contradiction and the dialectic contradiction.

By formal contradiction is meant, of course, the incompatibility of A and A' (negation of A): they cannot simultaneously be true. A formal analysis of them ends by proving their incompatibility.

Dialectic contradictions can be of two sorts: contradictions in the "gnosticological" sense of the word, and contradictions in the proper sense of the word. The former concern:

1. The contradiction between the imperfection of the knowledge obtained at each level of historical development and the

unlimited possibilities of knowledge, characterized by an inexhaustible source of objects studied and by their dialectic nature.

2. Contradictions between the knowledge accumulated by science and the limited possibilities for its application in practice.

3. Contradictions between the opinions, concepts and points of view of different groups of scientists. The conflict between opinions and concepts is often provoked not only by the existence of disputed questions in the technical, descriptive part of the science, but also by the diversity of interpretations of scientific facts even though determined by methodoligical and conceptional observations of scientists.

4. Contradictions between the results of theoretical knowledge with its abstractions, idealizations and simplifications on the one hand, and direct experience on the other: we are constantly led to identify the object as it appears in experience, with its idealized, simplified diagrammatical image, to identify the whole with a part etc...

5. Contradictions of conceptual activity which appear through the fact that in representing movement we make use of a series of "stills" in representing the continuous we bring it down to discontinuous quantities. In order to form a concept of the whole, we are obliged to divide it into a number of parts, the different by the identical, etc..., in other words we conceive the various characteristics of objects by means of their contradictions.

By dialectic contradictions in the proper sense of the word we mean those which at a certain initial stage appear in the form of dialectic contradictions i.e. of contradictions which in order to find the means to resolve them, oblige us to modify, perfect and develop our knowledge. They occur for example in the following cases:

1. Discovery of formal contradictions between on the one hand the postulates, axioms and confirmations of theories, and on the other experience acquired as a result of a subsequent study of the object which is also situated in the corresponding propositions; we then modify the theory (by changing components or by creating a new theory). In this case, the formal contradictions which we have discovered begin to appear in the form of dialectic contradictions.

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2. Discovery of paradoxical "proved" formal contradictions in logico-mathematical theories (e.g. the paradoxical contradiction discovered by Russell in the naive theory of quantities). The type of discovery obliges us to perfect or modify the theory, to reject certain assumptions and to replace them by others.

3. Sometimes formal contradictions of false reasoning, influenced by psychological reasons or by the complexity of the problems to be solved, also find their way into science. Sometimes their discovery also lead to a sudden startling development of knowledge. In this case they appear in the form of dialectic contradictions.

Let us now examine examples illustrating respectively 1., 2. and 3. above:

1. A number of propositions in classic mechanics have in the course of time become contradictory with experience. Thus it was originally proved, in conformity with the principles of classic mechanics, that the motive forces of gravity, electrostatics and magnetism, in obedience to the laws demonstrated by Newton and Coulon, act along a straight line joining the two bodies attracted or repelled and depend solely upon the distance between the bodies in question. Experiments carried out by Oersted and later by Rowland showed that dependent upon the speed of the charge a force perpendicular to the surface of a coil acts upon a magnetic needle placed within the surface of the coil through which the current passes. This was in contradiction with the specific fundamental propositions of classic mechanics quoted above. The experiment showed that the moving charge acting upon the magnetic needle does not set up forces of attraction and repulsion and does not act along a line between the needle and the charge, but acts perpendicularly to this line. The experiment also showed that the active force does not depend only upon the distance between the needle and the charge but also upon the speed of the charge.

The formal contradiction is obvious: the description of the particular experimental fact proves to be in contradiction with the general principles of the theory. It may be supposed that on the basis of the laws of formal logic, the general principle of the theory in its overall form is false. But the functions of formal

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logic cease with this observation. The discovery and accumulation of similar contradictions in classic mechanics raised the problem of the perfection of physical knowledge. At this stage the contradictions between the existing theory and experimental reality appear as dialectic contradictions. In point of fact, the transition from classic mechanics to "relativist" mechanics is achieved.

2. The appearance of paradoxical contradictions in formal systems obliges us to reconstruct the latter, to modify and to improve them (they then appear in dialectic form). To obviate the paradoxical contradictions in systems of the *Principia Mathematica* type, Russell proposed the theory of types which assumes the differentiation of various levels of abstraction.

The means for resolving the paradoxes may be different, but in all cases it is necessary to modify and perfect the theory, to reject certain more forceful idealizations and replace them by idealizations which may guarantee the elimination of paradoxes and the application of the laws of formal logic. This means that we had based the formalization previously reached upon certain abstractions and idealizations which proved improper. In this case "stopping" the movement for the purpose of studying it, was unsatisfactory.

3. Sometimes the solution of a scientific problem by material means, is based upon the analysis of the logical difficulties. In this case the logical errors no longer have a fundamental character. Thus for a long time the efforts of numerous mathematicians were directed towards proving the postulate concerning parallel lines without making use of other propositions of the same type, not then proved.

"The most natural means for solving this problem was the following: it was necessary to eliminate the *Data* of Euclid, the propositions by means of which postulate V is used directly or indirectly; it was also necessary to try to prove this theory on the basis of only those propositions which remained."

In the history of mathematics a considerable number of attempts of this sort exist. Most frequently the error accepted in these demonstrations consists of tacitly using a premise equivalent to the proposition which is to be proved.[8]

[8] S.A. Iakovskaya, *Avant-garde Ideas by N.I. Lobatchevsky: Materials to combat Idealism in Mathematics*, URSS, 1960, pages 5-6.

The discovery of these formal contradictions rids science of certain illusions, and stimulates and directs the quest of scientific thought. In this case the contradiction appears in its dialectic form.

v. Any scientific theory with its simplifications, vulgarizations, and idealizations find itself in a position of contradiction with the fragment of reality which it describes. This contradictory relationship can be characterized as dialectic in the "gnosticological" sense of the word (see paragraphs 4 and 5, page 29). It is solely through the fact that theory is created on the basis of limited experimental information that the idealizations introduced in the theory are directed so as to describe the experimental reality entirely, constructively and without contradictions. Thus we avoid certain aspects of the objects studied which are considered as unimportant. In addition, the introduction of idealizations is directed towards the concrete problems which must be resolved by the theory (thus it is natural to use an idealization such as the "material point" for the study of the movements of planets about the sun; this idealization has no longer any sense in the case of studies of the properties of the planets themselves).

Fully-developed and thorough experimentation, together with the problems which vary under the influence of scientific and social experiment, leads to the fact that our idealisations or hypotheses introduced into the theory find themselves in contradiction (still in the dialectic sense of the word) with experience and new problems. These dialectic contradictions oblige us to modify previous idealizations, the "conceptual" apparatus of the theory in general and sometimes lead to the birth of new theories.

The contradiction between theory (in the gnosticological sense of the word) and the fragment of reality under study always exists potentially in an implicit form. Under the influence of a new experiment (already explicit) it appears as a formal and then as a dialectic contradiction (in the proper sense of the word).

vi. In so far as theory, with its idealizations in contradiction with reality, "functions" well and is applicable in practice, we can make abstraction of its incompatibility with reality. It is the successful utilization of the theory in practice in its various applications which obliges us to accept such idealizations.

In the process of representation of motion in classic mechanics we use extreme idealizations such as the "point without dimensions" and "the moment in time without duration." There the means of representing motion consists of attributing to any moment in time (of a certain time-interval) the coordinates of the point in motion. In this case there is no formal contradiction and this occurs in the following circumstances:

1. In theory we leave only the strict raw idealizations;
2. Outside theory we reject them;
3. Anything which outside theory does not appear as an idealization is assimilated (by applying theory to practice) to the strict raw idealization accepted in theory.

Thus, in accordance with the movement represented, we declare that there are no intervals of time howevevr short which cannot be further divided and during which the moving body may not change its position. On the other hand we pretend to identify sufficiently brief intervals with "moments of duration". These values are examined as objects which really exist and are perfectly exact, contrary to their approximate significations. These perfectly exact values, which determine the position of the object at a given point, represent only a certain approximation to that which we are attempting to prove by means of them. These approximations which we "vulgarize" and "make absolute" enable us to ignore the imprecision of the limits of the body studied and to bring out the basic state of the body. By this blurring effect, we obtain answers appropriate to the problems with which we are concerned; there is no logico-formal contradiction, at least not immediately. We arrive at one, however, as soon as it is not capable of providing us with a complete description of the phenomenon under study, or when the aspects which we have ignored prove to be essential. But this contradiction is once more resolved by means of a certain new idealization, constructed now on the basis of knowledge previously acquired and not in a vacuum.[9]

[9] S.A. Iakovskaya, *Zeno of Elea*, in *Philosophical Encyclopedia*, tome 2, 1962, page 173.

VII. Thus scientific theories cannot do without idealizations. Their importance in the process of the representation of reality is immense. They are contradictory (in the gnosticological sense of the word) with reality. In this sense they represent truth in an incomplete, vulgarized and relative manner. There are however in such a case no formal contradictions. The acquisition of new experience, the appearance of new problems result in the discovery of formal contradictions in the theory with its former idealizations. These contradictions oblige us to perfect the theory and its idealizations and sometimes to move to a new theory. In this case the contradictions have already a dialectic character in the proper sense of the word. This is how the process of the development of scientific knowledge takes place.

What has been stated above means that scientific knowledge and scientific theories are continuously developing as a whole.

The value of scientific theory consists in its contribution to dialectic development; scientific theory also enables us to learn and to represent reality.