Irani, Kaikhosrow D.

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Organon 3, 63-69

1966

Artykuł umieszczony jest w kolekcji cyfrowej Bazhum, gromadzącej zawartość polskich czasopism humanistycznych i społecznych tworzonej przez Muzeum Historii Polski w ramach prac podejmowanych na rzecz zapewnienia otwartego, powszechnego i trwałego dostępu do polskiego dorobku naukowego i kulturalnego.

Artykuł został zdigitalizowany i opracowany do udostępnienia w internecie ze środków specjalnych MNiSW dzięki Wydziałowi Historycznemu Uniwersytetu Warszawskiego.

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MUZEUM HISTORII POLSKI

UNIVERSITAS VARSOVIENSIS

Kaikhosrow D. Irani (United States)

CONDITIONS OF JUSTIFICATION IN THE HISTORY OF SCIENTIFIC DISCOVERY

It is extremely difficult to formulate a precise and complete definition of science. This is because it consists of a variety of activities, it asks different types of questions and establishes different kinds of propositions. However, we will find agreement in the judgment that in science we attempt to discover the explanations of phenomena. In achieving this we construct universal propositions or law-like statements and establish them by empirical cofirmation. We also demand that the law-like propositions give formulations of the causes of events, or if they are functional relations between variables, the change in the value of one variable result in a change in the other. This is not to assert that there are no exceptions to these formulations, in any case, not only are these the most usual forms of laws but also these are the ideal forms of laws towards which scientific inquiry steadily aims. These laws then function as premises from which the phenomenon to be explained may be deduced. The establishment of these laws is considered in the standard treatment of traditional inductive logic or the more refined methods of the recently explicated hypothetico-deductive method.

The laws are themselves explained by the construction of theories. A theory is a set of propositions, which we may call postulates, from which the laws to be explained may be deduced. The distinction between laws and theories is that the terms in a law must be operationally defined, whereas the terms in the postulates of a theory are not so defined. What the theoretical terms such as "molecule", "atom", "proton", "light wave", "force field", *etc.* designate are unobservables. The establishment of theories is similar to that of laws; we deduce new observable consequences from the theories and verify them. However, there is an additional step here which must be noticed. To deduce observable consequences from postulates containing terms which refer to unobservables we must relate combinations of unobservable terms to observable terms. These semantic relations between two types of terms are sometimes called coordinating definitions or correspondence rules. Thus the deduced consequences of the theory are "translated" into the language of observation terms (which include operationally defined terms) and then verified. This type of establishment is called indirect verification. When a consequence of a theory is empirically falsified we subject the theory to some alteration until the conflict between the prediction and the observation is eliminated. The theory explains all the propositions, *i.e.*, laws or law-like statements that are deduced from it.

The significant criterion of justification for both laws and theories is the one of empirical verification of predictions. This criterion, as ordinarily understood, would force us to reject a law or theory when its predictions are empirically contradicted. The question that arises now is what precisely do we do when such a contradiction arises. We can always, or almost always, postulate the occurrence of some latent phenomenon, or the presence of a hidden entity or power which removes the contradiction, *i.e.*, which makes the contradiction a merely apparent one. Such instances are well known to the historian of science in the theory of planetary motion in astronomy, in early physiology, in the phlogiston theory, *etc.* What such a methodological procedure does is to make the theory quite unfalsifiable. To permit such a procedure would be, according to most methodologists of science, to fail to make the crucial distinction between science, on the one hand, and what is pejoratively called metaphysics on the other. Hence we add another criterion to the effect that if an existential proposition is added to a theory or law to "save" it from having its prediction contradicted, that existential proposition must of itself be independently empirically confirmed.

But consider now the postulation of the neutrino. The spectra of electrons in the beta-decay of radioactive nuclei contradicted the conservation requirements of quantum mechanical theory under which it was subsumed. The neutrino, a particle, was postulated with the appropriate properties and was assumed to leave the nucleus with the right velocity so that energy and momenta were conserved and the other requirements of quantum mechanics kept inviolate. The existence of the neutrino was empirically established two decades after its postulation, but its existence was assumed and utilized quite extensively before the empirical establishment was achieved. What methodological reason can we give for this acceptance which was obviously in violation of an empirical criterion of justification in science? We could have said that the process of beta-decay does not obey conservation principles, but it was felt that this would be, somehow, intolerable.

To investigate this situation let us first develop the notion of a conceptual framework. Most theories, but certainly, all theories with ontological postulates, have conceptual frameworks imbedded in them. By a theory with ontological postulates we mean a theory which asserts as one of its postulates that such and such a thing exists; for example, the postulates that molecules exist, atoms exist, mass points exist, etc. In such a theory, the phenomena it explains are always interpreted by some correspondence rules to be changes in the manifestations of the properties of these fundamental entities.

If a theory is very comprehensive and has extensive confirmation the conceptual framework of the theory comes to be considered as a true description of reality.

The conceptual framework of a theory is a qualitative statement of what we consider to be the fundamental existing elements and the ways their properties or relation change in time. Thus the conceptual framework usually consists of an ontological proposition and a dynamical proposition. There may also be some other propositions about the relations between the two. But the specific relations of the magnitudes of types of variations, *i.e.* the equations relating the entities and their properties, are strictly part of the theory and not the conceptual framework. Thus, for example, the conceptual framework of classical chemistry is that all substances in nature are elements or combinations of elements. There were 92 such elements. Furthermore, each element consists of atoms identical in weight and chemical properties. The atoms have fixed values and fixed affinities for other specified atoms. According to this conceptual framework every substance in nature is comprehended in terms of its structure, *i.e.*, the ingredient elements combined in various architectural forms in accordance with their respective valences and affinities; and all change of substances is comprehended as breakdown of the architectural forms, *i.e.*, the molecules, into their ingredients or the reassembling of some of the atoms into other molecules. What must be noticed here is that the conceptual framework does not itself constitute a theory, for, by itself, it predicts or explains nothing but formulates the general qualitative principles in terms of which the structure and function or transformation of all substances is to be interpreted. When theories of specific phenomena such as acid base neutralization, or structure and activity of aromatic organic compounds or electrolysis, *etc.*, were constructed specific postulates concerning the properties, valencies, affinities of individual elements were formed and operational tests for identifying the concepts or combination of concepts were constructed. The theory thus explains and predicts phenomena. In the course of its development as the theory is altered, corrected or extended the postulates change but they are all under the same conceptual framework. The conceptual framework provides the concepts and types of properties and relations from which the appropriate postulates of the theory are constructed. Thus different and even conflicting theories may be under the same conceptual framework.

Perhaps the most pervasive conceptual framework in the history of modern science is the one of Newtonian Mechanics. This may be somewhat incompletely formulated as follows:

1) All objects are collections of points having mass and location in an independent space and time system of coordinates.

2) All change in motion is the effect of forces acting on mass points and having the properties of vectors.

3) Several forces acting on a body can be added according to vectorial rules.

Any theory formulated within this framework would be required to provide techniques for measuring space and time and for specifying the values of various forces of which there may be many varieties. The theory must have also postulates relating the magnitude of the force to the magnitude of the resultant motion. Thus different specific theories may have different specific techniques and relations but still remain within the general type of relations which characterize the conceptual frame of Newtonian Mechanics. The conceptual frame will be seen to contain an ontological postulate (1), a dynamical postulate (2) which is a causal statement explaining change, and the other statement (3) is a way of dealing with multiplicity of causes.

Let us see how this conceptual framework functions. Suppose a physicist (Newtonian physicist) were examining a problem of motion. He would immediately consider the moving body as a collection of mass points. Upon these points he would assume some force to be acting such that change in motion was proportional to that force. Then he would use recognized techniques for identifying and calculating these forces. Suppose he was unsuccessful in discovering these forces, would he be inclined to reject the framework of mechanics? Of course not. He would say that somewhere or other there is a force to be discovered. The application of the conceptual framework has become for him the very condition of intelligibility of an explanation of motion. Fitting the phenomena of motion into this framework is what he means by explaining motion. The conceptual framework functions as a set of interrelated concepts into which the phenomena are translated and then the appropriate search for causes takes place in this translated schema.

We see now what happens in the history of a successful scientific theory. The theory is established as more and more verifiable consequences are deduced from it. The theory is treated as a highly confirmed set of descriptive statements. But then when some phenomenon falling within its scope is not obviously deducible from it we insist upon the phenomenon being interpreted in terms of the theory and produce other propositions for this interpretation to succeed. This is how the neutrino was postulated. At this stage the theory is functioning normatively and not just descriptively. The reason for its normative function is that the conceptual framework itself has acquired the status of a justifying principle. It is this normative operation which justifies the postulation of entities and properties of the type falling within its conceptual framework, even though their existence is not justified by empirical criteria. Of course, if the conceptual framework forces us to invent more and more entities for which no empirical evidence is found in future research the disutility of the theory increases and in the course of time a new theory emerges, and if such theories are repeatedly disconfirmed empirically the entire conceptual framework is replaced by another.

The reason why conceptual frameworks of successful theories have this normative power is that they incorporate descriptively conditions which satisfy some highly general criteria of scientific knowledge. This notion of the methodology of science can be explicated by construing its task to be the formulation of a set of meta-scientific principles to which we would refer in deciding on the acceptance or rejection of a proposition or theory into the body of scientific knowledge. If we believe the methodology of science to be what empiricism takes it to be then we have only two methodological principles: (i) that every proposition in the body of scientific knowledge must be empirically confirmed and (ii) that the set of all such propositions must not be inconsistent. But the functioning of conceptual frameworks indicates that the methodology of science is more complicated. It manifests the efforts of scientists to interpret and fit the data of observation into conceptual frameworks which implies that some other principles are at work.

It is generally agreed that we have a criterion of explanation in science. By this one means that a proposition cannot be permitted to remain in the body of scientific knowledge unless it explains other propositions or is itself explained. In other words, all the propositions of the body of scientific knowledge are bound into the deductive scheme of explanation; they appear as premises and explain or as conclusions and are explained. A proposition totally detached from the body of scientific knowledge constitutes a problem for scientific inquiry. It is also agreed that propositions accepted into the body of knowledge must be empirically confirmed, *i.e.* must have inductive support and thus lead to successful prediction. This is the empirical criterion. But there are other criteria. We shall mention only two: (i) the criterion of objectivity, *i.e.*, the independent existence and description of entities and events in nature, and (ii) the criterion of causality in terms of which all change is comprehended. These two criteria, even if rendered precise, remain quite abstract hence difficult to apply. The conceptual frameworks mentioned above are schemes which in their description incorporate these criteria and thus become conceptually effective means of interpreting phenomena in accordance with these criteria. This is the basis of their normative power. It would be wrong to think that conceptual frameworks are adhered to merely out of intellectual habituation or conditions or inertia, or that they are conventional accidents in the history of ideas. In part, they reflect the imaginative constructs of the scientific mind which may change from time to time but their function in the methodology of science rests on the incorporation of the epistemological criteria of science itself.

The history of science is not merely an account of the observations of nature, the discoveries of phenomena and the promulgations of laws and theories. It must account for the human activity of making judgments based on reasons by which propositions are included in or excluded from the body of scientific knowledge. The variations in the conditions for justification must be accounted for. Observations lead to the formulations of laws and theories justified by criteria of empirical confirmation.

But when a theory after undergoing repeated alteration and extension fails to account for the phenomena that it is supposed to explain its conceptual framework may be replaced by another and a theory under the new conceptual framework is formulated to explain the phenomena. The difference is a very significant one for the change of the conceptual framework indicates a deep or revolutionary change in our portrayal of nature. Compare the following two situations in the history of chemistry: (a) The changes in theories explaining the structure and substitution-reactions of benzene, and (b) the changes in the theories explaining combustion, especially in gases. In the first we had a series of theories all within the conceptual framework of organic chemistry, the new theoretical idea that emerged was that of the ring structure of benzene. Whereas in the second, the series of theories which were under the conceptual framework of the phlogiston notion steadily became extremely complicated and required so much imagination to render them consistent that the whole framework was dispensed with and combustion was brought under a new conceptual framework of the interaction of atoms of gases. There was no longer conservation of phlogiston, there was conservation of matter in combustion. It is important to note that the criteria embedded in both these conceptual frameworks were the same, only one happened to be a not clearly comprehensible picture of the world. In a sense then, conceptual frameworks are subject to empirical rejection; but it is not a straightforward empirical test to which they are subject, it is rather a gradual movement towards empirical disutility. It is not so much a wrong picture of nature as one which is incomprehensible and fading.

We must now look at another situation in the history of science. The replacement of Aristotelean physics by Galilean physics constituted a transformation of the conceptual framework. But in this situation, unlike the previous example, the criteria embedded in the conceptual framework were different. There was a shift in the ontological criterion from the concept of an object as belonging to some natural class to the concept of an object as an extended body in a spatial and temporal system. And the essentially teleological dynamical postulate of Aristotelian physics was given up in favor of a geometrical description of change. There was no clear formulation of a dynamical principle in Galilean physics. It did not come till the formulation of Newton's second law of motion. What we see here is a change of conceptual framework in which the very criteria of objectivity and causality were transformed. Thus this was a revolution in science which not only altered the theories of physics but also the very criteria of intelligibility which constitute explanation. It was not just a revolution in physics but in the epistemology of physics.

The explanatory principles of science are justified by empirical confirmation in the first instance. But later justifications come through the conceptual frameworks subsuming already existing, successful theories. These provide justification by reason of the fact that some criteria of justification are implicit in them. But the conceptual frameworks may alter, and in some instances of these alterations the criteria embedded in them are altered. History of science in its accounting of the development of scientific thought must disclose not only the facts of discovery and the conclusions accepted or rejected thereby, but, also the methodological grounds upon which they were based. Thus a history of science which ignores these variations in the schemes of justification cannot but fail in its appointed task.