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Edited by

HENK L. MULDER

and

BARBARA F. B. VAN DE VELDE-SCHLICK

With Translations by

PETER HEATH, WILFRID SELLARS,
HERBERT FEIGL and MAY BRODBECK



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2. EPISTEMOLOGY AND MODERN PHYSICS*

There is no longer any doubt nowadays, that theoretical philosophy has standing only in close connection with the sciences, whether it seeks in them a basis on which it attempts to build further, or whether they form for it merely the subject-matter of its own analyses, whereby it then makes individual inquiry into the first principles of knowledge. This is very much the case if, as I believe, philosophy can be nothing else whatever but the activity whereby we clarify all our concepts. And it is also beyond doubt that, of all the sciences, *physics* here stands at the forefront. Physics, that is, occupies an exceptional position, because in it two elements are united, which are only found separately in the other sciences: in the first place its exactness, the quantitative determinacy of its laws, whereby it differs from all other factual sciences, more particularly the historical sciences; and secondly the fact that it has as its subject-matter the *real*, and in this respect differs from mathematics.

Even a person who did not follow Kant, in permitting only absolutely certain, exact knowledge to count as knowledge at all, would yet be convinced that at any rate it represents the high point of knowledge, so that a philosophy which could do complete justice to exact knowledge would thereby at the same time have solved the *entire* problem of knowledge. But this it can do, however, only if it deals not merely with strict knowledge, but at the same time with knowledge of the *real*, since merely imagined or contrived objects are of little interest to the philosopher; it is the world of reality which yields him the major problems.

Hence the physical sciences are assured of having a unique significance for philosophy, though this has not always been apparent in equal measure to philosophers of different periods. After the making, in our own day, of some attempts that were already methodically defective, to couple the historical with the exact sciences from a philosophical standpoint, the modern development of physics, which has taken on a highly philosophical character, has

* 'Erkenntnistheorie und moderne Physik' (written in 1925), *Scientia* 45 (1929) 307–316.

Translated by Peter Heath.

brought out the peculiar position of this science a great deal more clearly than ever before. So clearly, indeed, that, given the present state of research, some altogether crucial questions about the mutual relationship of physics and epistemology can perhaps be brought to a decision.

The most important of these questions seems to me this: when, through alliance with exact empirical science, philosophy emancipates itself from the speculative procedure, does it acquire a better criterion of its own truth? Given a proposition of physics, we know how its truth can in principle be established: it has to be confirmed by experience. But the question of how we actually recognize the truth of a philosophical system is so far from having found a generally satisfying answer, that it has often been put forward only for the purpose of deriding philosophy.

Today, however, after the insight gained into the thorough interpenetration of philosophy and the sciences, we can and must say of *epistemology*, at least, that the correct theory is that which prevails in course of the advance of physical research.

But this formulation of the criterion of truth is initially so indeterminate and general, that we still need very accurate elucidations in order to understand its meaning aright. And here it is contemporary physics alone which provides us with the instances of cognition that are needed to specify and explain matters in full.

Before examining individual cases, we shall ask in what sense we can really expect beforehand to find epistemological statements confirmed in physics. Can philosophy predict any experimental finding of the empirical sciences? We certainly have no right to assume this, for if so, philosophy would be dabbling in the trade of physics, and nobody believes any more nowadays that physical results can be obtained by purely philosophical methods. The task of epistemology is not to predict what will be observed in nature. It merely tells us beforehand how science will react, *if* this or that is observed. What it prophesies, therefore, is not the results of experiments, but the impact of experimental results on the system of physics.

By far the most important limiting case of such statements occurs when it lays down specific principles with the claim that science will *always* adhere to them, *whatever* sort of observations may be made. In short, epistemology makes statements about the dependence of physics on, and in limiting cases its independence of, *possible observations*. The statements are correct when, on the occurrence of these observations, physical science actually takes the form predicted.

Here now is the weightiest example from modern physics. The episte-

mology pursued by the great mathematicians of the 19th century (Gauss, Riemann, Helmholtz) had maintained that a specific course of processes in nature (a specific mode of behaviour on the part of light-rays and measuring rods) was conceivable, on observation of which physics would turn over to employing non-Euclidean geometries. This prediction, as we know, has been most brilliantly confirmed by the general theory of relativity, and the premisses on whose basis this prophecy was made, have thereby demonstrated their truth-value. But what role did these premisses play in the epistemology of the said mathematicians? Do they form the inmost heart of their philosophy, determining the character of the whole edifice of thought, or are they of a less essential kind, so that they might perhaps equally find a place in an altogether different theory of knowledge? This question has to be answered in order to know in what degree and what aspect modern physics is actually to be seen as confirmation of that particular epistemology, which was notoriously that of *empiricism*.

An important step towards deciding the matter is taken if we establish whether, or in what degree, the opposite theory to empiricism, that of Kantian apriorism, would be equally capable of validating the principles of modern physics. This apriorism teaches, of course, that natural science will always adhere to certain general principles, *whatever* any given experimenter may happen to observe. These principles are said to be synthetic, that is, not to express mere tautologies, and they are also said to be *a priori*. The latter has a double significance in the Kantian system. First, that is, that they represent logical presuppositions of science, so that without them we could erect no structure of connected truths about nature at all; but secondly, too, that these principles are *self-evident* for us, so that we simply cannot imagine their invalidity, and hence that our ideational consciousness is inexorably linked to them. Of these two aspects the so-called logical interpretation of Kant (the Marburg school) emphasizes the first, while the psychological view stresses the second. The conflict between the two attitudes is strange, since both interpretations are quite indubitably combined together in Kant: synthetic *a priori* propositions are for him *both* the logically necessary presuppositions of science, *and also* imbued with the psychological compulsion of self-evidence.

Now which, according to the doctrine of apriorism, are the basic synthetic judgements of all science? For Kant, they include the axioms of Euclidean geometry, of which, as we have just seen, modern physics demonstrates that they are not *a priori* in the first sense, after it had already been made clear before this that they are not so in the second (psychological) sense. For in

that sense apriorism with regard to Euclidean geometry has already been refuted by psychological considerations, which many philosophers still seem to overlook.

In this one connection, concerning some (and hence not yet all) geometrical axioms, modern physics therefore opts decisively in favour of empiricism. But apriorism can take a variety of forms; its principle is elastic, and does not have to be defended precisely in Kant's version. It would be quite generally refuted only if it turned out that science contains no synthetic *a priori* propositions *whatsoever*. Anyone who maintains their existence must of course be able to produce them. An apriorism that cannot really enumerate a single synthetic *a priori* principle, has thereby pronounced its own death-sentence. For this reason I raised the question some years ago¹, as to which judgements about nature a modern apriorism would now be able to propose, in the light of contemporary physics, as absolutely inescapable presuppositions of all science, independent of any possible observations.

And to this question modern scientific research appears to give an answer of the same kind as that given in the case of Euclidean geometry; for it shows that physical science *refuses* to regard any one of the principles which might come into question here as the sole possible basis. In order to convince ourselves of this, let us go through the particular proposals which have been made for keeping apriorism on its feet!

In the first place, now that a portion of the Euclidean axioms has had to be dropped, the attempt has been made to extract a complex from the remaining axioms of geometry, and to proclaim it as the unshakeable foundation of all scientific accounts of space. Reverting to an older belief, it has been sought to ascribe this rank to the axioms of *analysis situs*, to those principles, that is, which describe the purely qualitative inter-relationships of space, without reference to 'metrical' relations of magnitude – in short, to the axioms of 'topological' space². But there are indications in modern physics that it has no wish to allow itself to be fettered for ever by such axioms. Hermann Weyl has already outlined a peculiar theory of matter³, according to which electrons, the ultimate constituents of matter, are as it were outside space. The latter would have such peculiar topological properties that it would be impossible, for example, to imagine a spherical volume of space containing electrons to contract by steady shrinkage into a point. Still bolder constructions are scientifically possible, and there is simply no predicting the assumptions to which we may be driven by the astonishing physical facts disclosed by modern research. Hence the appearance of contemporary physics gives us clear warning against the attempt to view

the topological axioms, say, as a *noli me tangere* [touch me not].

In the second place, the language of the new physics pronounces more clearly still against the endeavour to cling, say, to the *continuity* of nature as a necessary and invariably satisfied condition, which now finds expression in certain synthetic *a priori* propositions. For since Riemann, some decades ago, examined the physical possibility of a discontinuous space composed of discrete points, Planck's quantum theory, in our own day, has so domesticated the idea of jumpiness and discontinuity in our view of nature, that our physics is nowhere prepared to contest in principle the *possibility* of discontinuities. Here too, therefore, apriorism finds no resting-place.

Third and lastly, let us examine the attitude of present-day physics to that principle which appears in Kant as the most important of synthetic *a priori* propositions, and is also not infrequently declared to be such even today: I mean, of course, the *causal principle*. If, appropriately enough, we mean by causality the existence of regularity in nature, it certainly represents a necessary presupposition of science; without causality, a knowledge of nature would be impossible, for such knowledge consists, in fact, of discovering laws. From this simple fact many have already sought to conclude that the causal law is to be regarded as an *a priori* principle in the fullest sense. But this is undoubtedly quite mistaken, or at least a misuse of terminology. For this does nothing to establish an epistemological apriorism. The latter only comes about if we add the claim that we should continue to uphold the validity of the causal principle for all natural processes, whatever science may disclose to us in the way of facts in nature. In other words, we should have to possess an unshakeable conviction of the factual validity of the causal principle. We see here how the logical *a priori* is inseparable from the psychological, if it is to characterize a particular epistemological position, namely the Kantian notion that our understanding prescribes laws to nature. So when Ernst Cassirer expresses the opinion that the idea of universal regularity in nature, as such, continues to hold good as a synthetic *a priori* principle, or when J. Winternitz⁴, among others, describes the causal law as a constitutive principle of science in Kant's sense, the view of these exponents of a modified apriorism can only be understood to mean that they regard the possibility of science as absolutely assured, and consider a nature that would furnish no laws to man an absurdity.

As against this, it can be read off from the present state of physics, that science does not recognize *a priori* constraints of this kind, and opposes to the view in question the healthy scepticism of the empiricist. The pursuit of processes within the atom by the methods of quantum theory has led many

physicists to conclude that, within certain limits, processes that are strictly causeless occur there; to these, therefore, the causal law could find no application⁵.

Even if — like the author — one fails to perceive in the facts available any sufficient basis for this conclusion, it could still become perfectly legitimate if further facts were to hand, and so this case has the following lesson to teach: Although physics is well aware that the causal principle, the reciprocal dependence of natural processes on each other, is a presupposition for its own existence, it still by no means assumes this presupposition to be satisfied *a priori* everywhere, or even in a particular area; it ascertains for itself, rather, *using its own* methods (and with the exactitude of these methods), whether and to what extent this is the case. It establishes for itself, that is, the boundaries of its own kingdom. That the methods of science are able to make such an examination, can be confirmed by a subsequent analysis of its procedure. All this in contradiction to apriorism, according to which the causal principle is supposed not to be an empirically testable proposition.

The empiricist, of course, is well aware that it would always be *possible* in principle to sustain the causal law by suitable hypotheses — just as he knows that Euclidean geometry could be held valid without exception, if we really wanted this; but he denies that the human mind is unconditionally obliged to do this, and denies also that the application of scientific methods could always lead only to a confirmation of the causal principle. On the contrary, it is quite easy to imagine observations which would make it possible to sustain the causal law only by an infraction of these methods: namely, by a continual introduction of new hypotheses constructed *ad hoc*. And the modern physicist confirms the empiricist's prediction the moment he thinks himself actually confronted with observations of that kind.

Thus a survey of the state of modern physics indicates that it presents us in surprising sequence with a series of cases, in which the empiricist and apriorist views of natural knowledge may contend with one another; that without exception it pursues the course recommended by empiricism; and that not one of its principles is accorded those properties which a synthetic *a priori* judgement of the Kantian type would have to possess⁶.

We may say, therefore, that modern physics shows us, that even for epistemology there is a sort of confirmation by experience, an objective criterion of truth, and that this criterion decides in favour of the empiricist theory of knowledge.

A remark needs to be added, to guard against erroneous conclusions from what we have said.

The relation outlined between modern physics and philosophy could occasion regret that epistemology should cast the anchor of its criterion of truth into empirical science, and thereby partake of its uncertainty and mutability. But if the hope of grounding philosophy on a firmer soil than that of experience and logic must be abandoned (and it has never been more than a hope anyway), this would have to be set off in the bargain against the advantage of having obtained any objective criterion at all. It is very notable that an actual exponent of apriorism, Elsbach (in his book *Kant und Einstein*⁷), expresses the view that epistemology can be expected only to vindicate the mutable state of science at any time, but not science as such. This position is no longer that of Kantianism (Einstein, in his critique of Elsbach's book, says of him that he is in agreement neither with Mohammed nor with the prophet); it is more empiricist than empiricism. For the empiricist is unable to join in the lament of many onlookers, that physics is constantly changing, that its theories are short-lived and that hitherto supposedly correct laws are liable to be overthrown at any moment by new discoveries. He knows, rather, that no law till now, *in the sense and with the exactitude* whereby it has once been confirmed, has ever again had to be abandoned. The changeable elements in physics are not the relations of dependency, which once established, continue to find repeated confirmation, but rather the intuitive ideas which serve for interpretation and interpolation. The split between the purely conceptual and empirically confirmed content of a science, and the intuitive images which illustrate the content without themselves belonging thereto — this split is one of the most important achievements of modern epistemology. A philosophy that knows how to achieve it tidily everywhere may justifiably regard a confirmation by modern physics in the sense outlined above as a confirmation by science as such.

NOTES

¹ 'Kritizistische oder empiristische Deutung der neuen Physik?', *Kant-Studien* 26 (1921) [Engl. by P. Heath, *Phil.P. I*, no.13].

² Cf., say, R. Carnap, *Der Raum*, supplement (Ergänzungsheft) 56 to *Kant-Studien* (1922).

³ H. Weyl, 'Was ist Materie?', *Die Naturwissenschaften* 12 (1924), pp. 57f.

⁴ *Relativitätstheorie und Erkenntnislehre*, Teubner, 1923, p. 206.

⁵ These lines, like the whole essay, were written in 1925; the view here expressed has since received further confirmation.

⁶ To avoid misunderstandings, it should be emphasized once more that in practice, even for empiricism, science contains propositions that are not acquired through experience, namely definitions, of which the concealed definitions are the most interesting. They include the so-called 'conventions'. Like all definitions, they are essentially arbitrary and contain no knowledge, and hence are not synthetic in the Kantian sense. They are chosen as seems most suitable for the purpose of science (to describe the world by means of a minimal number of concepts), and can be replaced by others in the course of scientific progress. They are, of course, *a priori* in the sense in which any definition, any analytic judgement, is *a priori*. The acknowledgement of their existence is perfectly self-evident and has not the slightest relevance to Kantianism.

⁷ [A. C. Elsbach, *Kant und Einstein. Untersuchungen über das Verhältnis der modernen Erkenntnistheorie zur Relativitätstheorie*, Berlin 1924.]