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Book Reviews

Particles and Waves: Historical Essays in the Philosophy of Science, by Peter Achinstein. New York and Oxford: Oxford University Press, 1991. Pp. 337. P/b £17.95.

Peter Achinstein's impressive book consists of a series of essays in what might be termed "old style" philosophical analysis of the history of science. Achinstein focuses on the way in which evidence impinges on genuinely theoretical claims involving unobservable entities. He sees one argumentative strategy for the legitimacy of theories and their associated entities cropping up time and again across a variety of historical cases. No need then, against the current trend in historical studies of science, even to mention the psychological or social circumstances of any scientist; no need to worry about change in methodological standards—at least in this respect, it is "one big seminar in the sky", conducted according to fixed evidential rules.

Three episodes involving disputes about theoretical entities are discussed in detail: the eighteenth and early nineteenth century wave-particle debate about the nature of light, Maxwell's initial development of the statistical-kinetic theory of gases, and J. J. Thomson's contributions to the late nineteenth century debate on the nature of cathode rays. The book divides into three parts corresponding to these historical episodes—each part consisting of an introduction and a number of separate essays (three concerning particles versus waves, four on Maxwell and one on Thomson). Six of these eight main essays have been published before as independent journal articles.

As readers of these earlier articles will be aware, Achinstein's central methodological thesis is that the introduction of genuinely theoretical entities is *not* legitimated simply by the ("hypothetico-deductive") argument that the theories involving those entities yield correct empirical predictions (and neither was that the argument that as a matter of fact swayed the chief scientists involved at the time). Hypothetico-deductivism is, on Achinstein's view, rendered hopeless as a philosophical thesis by the fact of underdetermination—lucky then for the rationality of science that it is not the argument standardly employed as a matter of historical fact. Instead the legitimating arguments have and had a double structure: not only do the theories have the right empirical consequences but they also have "independent warrant". Achinstein takes independent warrant as equivalent to high *prior* probability (where probability is assumed to be a measure of *rational* credibility).

How does a theory acquire "independent warrant" or a high prior probability? Much of the book consists of a series of overlapping attempts to answer this question. As Achinstein himself characterises its "simplest case", the "causal-inductive" argument involved bears a close resemblance to Newton's famous "vera causa" principle. Some entity (e.g. a light beam) exhibits some observable property P (e.g. of "interfering" with other light beams). P is known to be exhibited by *other* entities which are, moreover, known to exhibit P in virtue of having structure S (in this case, disturbances transmitted through, say, water interfere because they consist of waves). It is inferred that probably light's exhibiting P is also caused by its having structure S (i.e. consisting of waves) even though in the case of light, its constituent waves (if they exist at all) are unobservable. Hence the theory that light consists of waves is given a "warrant" independently of any explanatory achievements.

Achinstein points out one immediate complication: that, for a range of properties P, more than one structure may be known to result in the exhibition of P. (For example, the property of moving from one point to another in a finite time is one that light shares *both* with material particles *and* with water waves.) In such cases, the main argument is to be supplemented by a sub-argument showing that alternative theories are improbable. This sub-argument may be direct (there are other properties P′ that material particles exhibit but that light does not) or indirect (there are properties P″ that light has but material particles would not exhibit unless certain very special auxiliary assumptions were true of them, assumptions which are themselves highly improbable).

Achinstein's argument, if somewhat repetitive (because previous articles have been republished with no attempt to remove overlap), are admirably clear, and his historical scholarship impressive. I wonder, however, if the contrast between his "inductive" method and "hypothetico-deductivism" is quite as sharp as Achinstein's treatment (usually) suggests it is.

Everything depends, of course, on exactly how the slippery notion of "hypothetico-deductivism" is characterised. But assuming its defenders are allowed to invoke (admittedly so far not satisfactorily analysed) notions like unity and simplicity, and hence make a distinction between a theory's explaining a phenomenon and *merely* entailing a correct description of it, then several aspects of Achinstein's "inductive" method seem to be equally available to them. Moreover, since any hypothetico-deductivist worth her salt surely requires the best confirmed theory to do a *better* job of explaining the phenomena than its known rivals, that part of Achinstein's argument for independent warrant that involves eliminating possible alternative theories (including the possible sub-argument that the auxiliaries necessary to reconcile an alternative theory with certain phenomena are *ad hoc* and improbable) is equally available to her.

What seems clearly *un*available to anyone likely to count herself a hypothetico-deductivist is any analogue of the "pre-eliminativist" part of Achinstein's argument. The hypothetico-deductivist is surely committed to the idea that the "context of discovery" is quite separate from the "context of justification", and hence that considerations of the logic of confirmation begin with whatever rival theories *happen* to be "on the table". But Achinstein insists that the wave theory of light, for example, did not achieve independent warrant in the early nineteenth century simply because there were reasons to eliminate its only *known* rival, the corpuscular theory, but instead because there were prior reasons to think that the wave and corpuscular accounts of light are the *only* genuine possibilities (or at any rate the only possibilities that have any substantial degree of (rational) probability). This pre-eliminativist characterisation of what might be called the "possibility space" is what really distinguishes Achinstein's strategy from anything hypothetico-deductive.

Achinstein's account of this distinctive part of his strategy is roughly as follows (again taking the case of light as illustration). Various general features that light exhibits (such as travelling from place to place in a finite time) are features that "one *observes* ... occurring [in other cases in nature either] by the transference of particles or by a wave movement" (p. 28; my emphasis). Hence it is at least probable that light too consists—though unobservably—either of material particles or of waves.

Achinstein is surely correct, and importantly correct, that some sort of argument of this kind is a significant, and until recently largely neglected, part of the argument for the acceptance of scientific theories. However, the particular account he gives of it is, I believe, inaccurate. First, by far the most important other case in this debate was that of sound, where the conclusion that it consists of waves was certainly not a matter of pure observation unaided by substantive theory (nor is it purely an observational matter in the case of water "waves" either, at least not if we mean by "wave"—as we certainly do when talking of the wave theory of light—something more precise than just any sort of transmitted disturbance). In general the identification of alternatives is seldom, if ever, a matter of "seeing" structures exhibited in other cases. Secondly, by whatever route we obtain the conclusion that other cases exhibiting the property at issue are all cases of either particles or waves, the argument that this makes it highly probable that light exhibits the property because it too consists either of particles or of waves is surely, as it stands, pretty weak. It might after all just be a coincidental feature of our investigations so far that we have only "found" the property exhibited by particles of some sort or by waves of some sort. Our sample of physical structures so far investigated might not be representative of the universe in general.

Whatever may be the case with other "inductive leaps" this one can be, and indeed was, bridged. The early nineteenth century argument that particles and waves are the *only* open possibilities for light is, I believe, both more convincingly and historically more accurately construed as one beginning, not from mere observation, but from basic propositions that were part of (then unquestioned) "background knowledge". Here, the crucial part of "background knowledge" was the basic assumption of mechanism, that all that *exists* in the physical realm is matter in motion. Hence (roughly): light *must* consist either of matter or of motion. Various non-particulate versions of the material hypothesis—such as the continuous stream theory—do not work, and neither do "combined" theories: leaving particles against motion. But the motion begins in a source—say the sun—and *some finite time later* arrives at a detector—say a human eye. Where was the motion in the meanwhile? "Disembodied" motion is banned (again courtesy of "background knowledge"), and hence a material substratum is required to "hold" the motion between source and receptor. Finally, it was also part of background knowledge that light, whatever it might consist of, must have periodic properties; hence if light does consist of motion transmitted through a medium it must consist of periodic waves in that medium. So, particles versus waves in a medium.

But if this is a (still simplified but) more accurate account of the argument, then, since it makes that argument rely on obviously theoretical rather than observational premises, the question of the credentials of those premises clearly arises in turn. The principle of mechanism was undoubtedly firmly entrenched in eighteenth and early nineteenth century "background knowledge" but was nonetheless clearly a theory. In order to give a full rational reconstruction of the argument we must in turn look into the credentials of this very general theory (and indeed of other parts of "background knowledge" at the time). These credentials, I believe, crucially involve the predictive success of particular theories incorporating that general theory. Given the mechanistic assumption and given the failure of alternatives, the early nineteenth century wave theory of light may indeed have possessed a warrant to some degree independent of its own predictive virtues, but not independent of the predictive success of then accepted theoretical science more generally.

Roughly speaking then, I believe that Achinstein's notion of independent warrant is—*via* its "pre-eliminativist" component—"onto something" important, but does not capture it entirely accurately; and further that the inaccuracy leads him to underestimate the significance of predictive success. Despite this (and indeed in part because of it), his clear and historically sensitive account of the argument from evidence to evidence-transcendent theory constitutes an indispensable starting-point for further methodological discussions both of the particular historical episodes it analyses and of the general issue of the role of evidence in the acceptance of scientific theories.

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Entailment: The Logic of Relevance and Necessity, Volume II, by Alan Ross Anderson, Nuel D. Belnap, and J. Michael Dunn. Princeton: Princeton University Press, 1992, Pp. xxvii + 749. £32.25.

The tale of Relevance Logic and Entailment continues with this book much in the same style as Volume I. The chapters are as eclectic as in Volume I and, depending upon the reader's background, reading the last chapter immediately after the first would be beneficial. The chapters start at VI taking into account Volume I; our chapter references use "first", "second", etc. The opening chapter, The Theory of Entailment, contains some of the same endearing polemic as in Volume I. For example, p. 7, "It is disquieting to be told that righteousness demands allegiance to truth values alone and that propositions are only for the unregenerate who hanker after spooks." This chapter presents propositional quantifiers and makes some case for them as more basic and natural than individual quantifiers—objections to propositions are handled with the argument that they are on a par with the idealized elements of mathematics, e.g., points, lines, etc., that have "no parts". Inherent in this point of view are the Fregean notions of *Sinn* and *Bedeutung*. These have been part and parcel of relevance logic since its conception.

The last chapter, Applications and Discussion, takes a critical look at the issue of negation within relevance. Here, relevance is treated as a philosophical system for reasoning. At best, this issue of negation can be phrased as "murky" and is acknowledged as such by the authors. The upshot is that Boolean negation is for the reasoner who has total knowledge of the world, something classicists almost, but not quite, fail to disavow their belief in. The DeMorgan negation of the relevantist may not be perfect for such aspirations as reasoning; however, this negation certainly has the property of preventing unwarranted conclusions from possibly corrupted data. Maybe as a salve, but certainly as an existence proof of utility, this chapter also goes on to explain what use the concept of relevance has within computer science. The main thesis here is that the world is imperfect and these imperfections are built into computer systems. What better vehicle for a computer in reasoning with incomplete and often contradictory data than a logic of relevance. We think of this term "reasoning" here not in the traditional anthropomorphic sense but rather in the ersatz imitation of "reasoning" used within a computer system.

The second chapter, Individual Quantification, treats classical theorems of quantificational logic where the quantifiers range over individuals. The authors show due respect for the fathers of modern logic and manage to put the relevant gloss on their work. Gödel's Completeness Theorem for first order logic, the Löwenheim-Skolem Theorem and Gentzen's Cut Elimination Theorem are covered. The chapter finishes with algebraic semantics for first order, first degree relevance logic and the admissibility of the γ rule (from *A* and *A* v *B*, derive *B*) in the full quantificational systems for $\mathbf{R}^{\forall\exists x}$ and $\mathbf{E}^{\forall\exists x}$. The first is relevance logic endowed with quantification over individuals and the second is the entailment logic similarly endowed.

The third chapter, Ackermann's Strenge Implikation, deals with Ackermann's work on a classical two-valued calculus, and a system equivalent to the authors' system **E** with the γ rule (disjunctive syllogism) added as primitive.

The fourth chapter, Semantics, covers Kripke-style semantics for relevance systems. With the authors' leave, this reviewer places Urquhart's semi-lattice semantics in the area of Kripke-style semantics in that the mechanisms of the