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COMMENT: DUHEM'S MIDDLE WAY

ABSTRACT. Duhem attempted to find a middle way between two positions he regarded as extremes, the conventionalism of Poincaré and the scientific realism of the majority of his scientific colleagues. He argued that conventionalism exaggerated the arbitrariness of scientific formulations, but that belief in atoms and electrons erred in the opposite direction by attributing too much logical force to explanatory theories. The instrumentalist sympathies so apparent in Duhem's writings on the history of astronomy are only partially counterbalanced by his view that science is progressing toward a 'natural classification' of the world.

In Duhem's writings about the nature of science, there is an ambivalence that even the most casual reader can scarcely miss. His account, in consequence, does not fit into the usual categories of the philosopher of science. He was, it seems, quite consciously trying to thread a middle way between two positions he regarded as extremes. One was what would today be called scientific realism, in the most usual sense of that much-distinguished phrase, that is, the view that the explanatory success of a scientific theory gives one valid (even though rarely conclusive) reason to believe in the existence of the underlying entities postulated by the theory. Duhem strongly rejected what has come, by a clumsy phrase, to be called 'inference to best explanation', holding on both historical and logical grounds that the explanatory power of a structural theory cannot serve as a testimony of its truth.

On the other hand, he was equally unhappy with the conventionalism of Poincaré and the inductivism he found in the physics textbooks of his day, because he thought that they unduly limited the truth-claims of science either by exaggerating the arbitrariness of the scientific formulations, as in the case of conventionalism, or by undervaluing the symbolic character of physical theory and the holistic character of its associated warrant, as he held inductivism to do. His distinctive notion of natural classification expresses his attempt to separate himself from the skepticism he saw as inherent in the two dominant fashions of the day in French philosophy of science, without at the same time embracing the model-realism he liked to associate with the 'broad but weak' English mind.

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By intention at least, then, he was neither a realist nor a skeptic about physical theory, in the most usual senses of those two elastic terms. In a move reminiscent of Arthur Fine's recent attempt to find a middle way between realism and instrumentalism, he proposed a definition of physical theory that allowed him conclude that:

> What is lasting and fruitful [in physical doctrines] is the logical work through which they have succeeded in classifying naturally a great number of laws by deducing them from a few principles; what is perishable and sterile is the labor undertaken to explain these principles in order to attach them to assumptions concerning the realities hiding underneath sensible appearances. (1914, p. 38)

The 'natural ontological attitude' he advocated, to appropriate a phrase coined by Fine, is to suppose that even though physical theory is incapable of itself of discovering entities that do not belong among the sensible appearances:

> The more complete it becomes, the more we apprehend that the logical order in which theory orders experimental laws is the reflection of an ontological order, the more we suspect that the relations it establishes among the data of observation correspond to real relations among things, and the more we feel that theory tends to be a natural classification. (1914, pp. 26–27)

Notice the language Duhem uses when he describes how we come to this belief: "the more we apprehend . . . the more we suspect . . . the more we feel . . .". Even though the convergence of physical theory on the relational structure of the world cannot be demonstrated by the methods of physical science itself, it is the natural attitude for scientists to adopt, and is supported by philosophic consideration of the history of specific theories.

Duhem walked a tightrope, to be sure. On the one hand, he found himself in disagreement with the most illustrious French exponents of the new discipline of philosophy of science, Henri Poincaré, Eduard LeRoy, and Abel Rey, who seemed to want to reduce science to a set of practical prescriptions for action, depriving it of its status of objective knowledge, as Duhem understood that phrase. On the other hand, he was scornful of the attempts of the most distinguished physicists of the day to construct theories involving unobservable entities like molecules, atoms, and electrons. Despite the fact that such theories "would undoubtedly be regarded as prophetic forerunners of the theory destined to triumph in the future", despite the 'almost universal assent' favoring them among working scientists themselves, he urges his readers to set

them aside and to learn from the study of "the errors of past centuries" to be on guard against those "efforts of the mind that wishes to imagine what ought to be merely conceived" (1905, p. 304).

But Duhem did not want to appear entirely out of step. He tried to put the best face on his disagreement with Poincaré and Mach, claiming to find a tension, amounting at times indeed to logical contradiction, in their work. Besides their usual stress on scientific law as convention or as convenient summary, he reminds us that they also on occasion allow, indeed insist, that physical theory leads to the discovery of the real relations of things with one another (1908b, pp. 327–35). He traces this tension in their thinking to the complex character of the question itself. A logical analysis of the experimental method can never of itself warrant anything more than the claim that physical theory serves an instrumental function as a predictive device. It could not, for example, forbid the simultaneous use of incompatible theories, provided they served the purposes of prediction. Working scientists could never be content with this; yet their conviction that such incoherence must be eliminated cannot be justified merely by an appeal to convention or to instrumental convenience.

It derives, he argues, from an intuition which clearly transcends the limits of science. Those who subscribe to a generally positivist ideal of knowledge face a dilemma, then. If they allow progressive unification of laws as a requirement of good science, they seem to violate the positivist canon; if they do not, they are likely to "shock most of those working for the advance of physics" (1905, p. 294). This is how Duhem excuses those whom he criticizes so gently: their heart is in the right place, he tells us. When they err, it is by understatement, it is only because they fail to realize that they do not need to take positivism quite so literally. He is not nearly so tolerant of the other extreme, of the 'atomists', as he calls them generically, those who believe that the explanatory power of theory allows us to penetrate beneath the level of sensible appearance. Their imaginative excess is more dangerous than positivist defect because of its allure, to scientists and nonscientists alike.

In his essay, 'Duhem's Conception of Natural Classification', Andrew Lugg focuses on Duhem's doctrine of natural classification in order to argue two theses, first, that despite appearances to the contrary, Duhem was not an instrumentalist, and second, that equally despite appearances to the contrary, he was a realist, advocating a version of conver-

gent realism. I would agree with him on the first of these theses, with some reservations, but would deny the second.

The instrumentalist thrust of *To Save the Phenomena* is well known. Duhem traces the debates in astronomy between the 'mathematicians' whose aim was merely to find a formalism that would fit the phenomena and the 'physicists' who wanted to explain the planetary motions in causal terms.[1] His sympathies are clearly with the former in the period prior to Galileo, when the explanatory schemes of the 'physicists' drew their warrant mainly from metaphysical principles in regard to causal action and hardly at all from their ability to save the phenomena. The concluding sentences of the book are worth pondering:

> Despite Kepler and Galileo, we believe today, with Osiander and Bellarmine, that the hypotheses of physics are mere mathematical contrivances devised for the purpose of saving the phenomena. But thanks to Kepler and Galileo, we now require that they save all of the phenomena of the inanimate universe together. (1908a, p. 117)

Duhem leaves us in no doubt that he believes Copernicus and Galileo were wrong, in principle, to suppose that their astronomy could allow them to claim that the earth is in motion. Their contention that their hypotheses bear on 'real movements' was 'false and harmful', and Osiander, Bellarmine and Urban VIII were right in viewing it as 'contrary to logic' (p. 116). There is no suggestion here (as there is elsewhere in his work) of a 'higher logic' that could later reverse this judgment.[2] Insofar as Kepler and Galileo are given credit, it is for their unification of earth and heavens in a single mathematical scheme, a unification that Newton carried to completion. This overcame the sharp dichotomy between the instrumentalism and the realism of earlier astronomy, and was thus the first major step to a natural classification. So despite Duhem's insistence that it was the 'mathematics' and not at all the 'physics' of that earlier period that would bear fruit, he still manages to find a precarious middle way, one that leans, however, rather more in one direction than the other.[3]

Duhem criticized the overly instrumentalist tendencies he detected in the conventionalism of Poincaré and the positivism of Mach, because they fail to account for the progressive unification to which the history of science gives unequivocal testimony. Though there are discontinuities in the history of physical theory, Duhem insists that these are on the side of *explanation*; the metaphysical fashions controlling such explanation come and go, like the ebb and flow of the tide (1914, p. 39). On

the side of *representation*, however: "each theory passes on to the one that follows it a share of the natural classification that it was able to construct" (pp. 32–33).

One is reminded here of Kuhn, who stresses the discontinuity that characterizes the development of explanatory theories (and is led, like Duhem, to reject scientific realism on that account) but still wants to insist on the overall progress in puzzle-solving and the cumulative character (in one sense at least) of experimental laws. Like Duhem, he insists also on the objectivity of scientific knowledge, despite his rejection of explanatory ontologies. Kuhn bases this claim on the fact that theory-appraisal is guided by values, over and above predictive accuracy, that are themselves relatively "permanent attributes" of science; again, the resemblance to Duhem's argument is striking. Kuhn would no more want to be thought an instrumentalist than did Duhem, but his defenses against the charge might be thought less secure, since he could not call on so ontological a ground as Duhem's natural classification.

Lugg notes Duhem's criticisms of the two doctrines from which the instrumentalism he questioned might derive. Yet Duhem's differences with the two seem at times more of the nature of family quarrels. He argues that Poincaré's conventionalism makes him unable to account for the part played by theoretical interpretation in the statement of experimental facts. Yet he also describes the principles of his own energetics as "pure postulates or arbitrary decrees of reason" (Duhem, 1917, p. 1), validated only by the conformity of their consequences with experimental law. The conventionalist emphasis on the arbitrariness of symbolic formulations is not without virtue in his eyes, it would seem, though it is in the end qualified, of course, by the doctrine of natural classification.

Duhem is even gentler with positivism. He opens section 2 of 'Physics of a Believer' with the words:

> We should like to prove that the system of physics which we propose is subjected in all its parts to the most rigorous requirements of positive method, and that it is positivist in its conclusions as well as its origins. (1905, p. 275)

It is true that this essay, preoccupied with showing that he did not, as his critics charged, make his physics subservient to a metaphysics, is more emphatic about the virtues of positivism than anything else he wrote. Nevertheless, his insistence on the "essentially positivistic"

character of his account of physics (p. 279) was genuine. He could applaud positivism for its exclusion from science proper of metaphysics in any form. He could identify with the positivist denial of "any ability [on the part of physical theories] to penetrate beyond the teachings of experiment or any capacity to surmise realities hidden under data observable by the senses" (p. 274). By arguing that physics was both autonomous and yet in a fundamental sense incomplete, he could retain positivism in one area while flatly contradicting it in another. Because, of course, his insistence on the legitimacy of a metaphysics violated the fundamental principle of Comte in regard to positive knowledge. Duhem plays down this disagreement; the alliance with positivism was crucially important to him. Though Lugg is clearly right to maintain that in the end Duhem was in the strict sense neither a positivist nor a conventionalist, it is important to stress how strong his affinity was with both doctrines.

Lugg's second thesis, cannot, I think, be sustained. He takes Duhem to be a realist, in the sense of holding that "the furniture of the world is more or less what our latest theories pronounce it to be". Further, he takes Duhem's opposition to atomism and mechanism not to be one of epistemological principle; it is only, he thinks, a matter of the inadequacy of the evidence as yet available in their favor. The trouble with them "is not that they cannot (in principle) be made good but that they have (as a matter of fact) never been made so".

Here I find myself in strong disagreement, though I realize that the matter is not cut and dried. Duhem's objections to the use of retroduction within physics itself to infer to the existence and nature of entities that lie beneath the level of sensible appearance, are assuredly a matter of principle for him. Lugg argues that Duhem's often-repeated view that physical theory cannot penetrate beyond the sensible appearances has to be read in the light of his distinction between the physicist's viewpoint, taken narrowly, and the larger perspective afforded by intuition and philosophical argument. But all that the distinction warrants in this case is the claim about natural classification: that physical theory, considered as a set of abstract laws, mirrors the underlying relations between things more and more exactly. Does Duhem envisage that molecules, atoms, electrons, and the like may one day become part of the natural classification? Quite clearly not, it seems to me.[4] If this were to be even a possibility, his arguments against mechanism would

fail, and his strictures on explanatory models would have to be discounted as referring only to their use up to the time at which he wrote. I can find no basis in his text for such a construal.

The only kind of realism that we can claim for him (and it is, of course, a crucial one for him) is that of the relationships he found in the laws of mechanics or, more generally, in what he called "energetics". It is not a realism of explanatory theory. The distinction between law and theory which is common today he did not make. For him, the explanatory aspects of the physical theories of his day, those involving unobserved entities causally responsible for the data of experiment, were excess baggage, illegitimate indulgences of the imagination. Would he have allowed retroduction in areas other than the microworld, in astrophysics or geology, for example? It is not clear. Is he, to speak very loosely, in the early lineage of van Fraassen or of Laudan? Is he prompted by an empiricism that would disallow any attempt to postulate entities that are in principle unobservable? Or is he motivated by a distrust of the ontological significance of explanatory models in any domain of science, whether micro or macro?

Lugg notices that the arguments Duhem employs for the ontological significance of the classifications found in physical theory are remarkably similar to one set of arguments used by contemporary defenders of scientific realism. Duhem notes the fertility and the unifying power of the abstract laws of physics, and urges that these cannot possibly be an "accident"; they are best explained by supposing these laws to reflect "realities whose essence cannot be grasped by [the] methods [of science], . . . arranged in a certain order which physical science cannot directly contemplate" (1905, p. 297). Here (as Lugg remarks) is inference to best explanation at the meta-level, more problematic in Duhem's use of it than in that of the contemporary realists who do not (as he does) implicitly question its validity at the object level. Why did it not occur to him that the sort of argument he uses for his realism of relations could just as easily be used for a realism of micro-entities?

Perhaps it was because these hidden entities seemed to him so remote from human modes of perception and conception; they could be reached only in imagination, and he distrusted imagination. But as he scrutinized the historical record, the role played by metaphysics seems to have bothered him even more. Only by drawing upon a cosmology that legislated the acceptable sorts of entity and the permissible modes

of interaction could the theorist (it seemed) construct a causal account of what supposedly goes on beneath the accessible surface of appearance. Not only are the facts of science theory-dependent, but explanatory theories have always been metaphysics-dependent. And this second sort of dependence has not been beneficial; atomists, Cartesians, and others have imposed their own notions of mechanism, and none have found any lasting success. A theme to which he returns again and again, one to which he clearly gave emotional as well as intellectual weight, is the importance of recognizing the basic autonomy of physics. The progressive unification which has gone on since Galileo's day has proved, he asserts, to be in no need of the imaginative dress of cosmology.

Duhem clearly thinks of metaphysics as a contaminant in the earlier story of physical theory. Because the physicist wrongly aspires to penetrate to bodies beyond the level of perception:

> He no longer has the right to shut his ears to what metaphysics wishes to tell him about the real nature of matter; hence as a consequence, through dependence on metaphysical cosmology, his physics suffers from all the uncertainties and from all the vicissitudes of that doctrine. (1917, p. 1)

His theories are thus "condemned to perpetual reformulation", and cannot assure the consensus and progress of which science is capable.

Duhem's attitude to metaphysics is puzzling.[5] On the one hand, in passages such as this one, he appears skeptical of the insights it claims into the true nature of physical things. On the other, he is careful not to deny its legitimacy as an autonomous mode of inquiry: "Our inquiry concerning physics has not led us either to affirm or deny the existence and legitimacy of methods of investigation foreign to this science" (1905, p. 280). Indeed, he argues that metaphysics and physics ought ultimately converge on the same natural classification, and suggests that the cosmology towards which his favored science of energetics is tending is the Aristotelian one, rid of its "fossilized doctrines" (1954, p. 308). What might give cosmology access to the structure of the physical world independently of scientific inquiry he never discusses. Are we to suppose he is speaking here as a Catholic apologist? And if we are, must this be thought to be merely a strategy on his part or a founded belief? Difficult but important issues, ones that cannot be addressed in short compass.

From the standpoint of contemporary scientific realism, Duhem appears to have seriously undervalued the resources of retroduction.

Imagination is not as dependent on prior cosmological commitment as he supposed, and the criteria of fertility and unification that he valued can direct imagination more effectively than he allowed. It is true that in the historical cases he studied, the warrant for ethers and atoms lay not so much in their contribution to a predictive model as in a prior philosophy of nature. It is also true that his focus was on mechanics where the purchase of realism has for quite specific reasons always been precarious. Had he looked more closely at the structural sciences of his own day, he might not have been quite so pessimistic about the ability of the theorist to divine the shapes of entities that escape the contingent modes of human perception.

NOTES

[1] Historians have been critical of Duhem's instrumentalist reading of the Platonic tradition of 'saving the phenomena'. The commitment to circular motions and uniform speeds of rotation would of itself suggest that the mathematical formalism was not chosen on merely pragmatic grounds; the circular motions were in some appropriately qualified sense regarded as real. And Duhem too easily ascribed straightforwardly instrumentalist views to writers such as Ptolemy whose real views were undoubtedly much more mixed. See G. E. R. Lloyd, 'Saving the Appearances', *Classical Quarterly* **28** (1979), 202–22.

[2] R. N. D. Martin is at pains to argue that Duhem's apparent support for Bellarmine and Urban and his criticism of Galileo must not be taken as an attempt on Duhem's part to vindicate the action of the ecclesiastical authorities in 1616 ('Saving Duhem and Galileo', *History of Science* **25** (1987), 301–19). Martin recalls Duhem's dictum that "pure logic is not the sole guide of our judgements", and suggests that the fact that Galileo is criticized here for his faulty logic ought alert us that "reasons of the heart" might (in Duhem's view) have been operating under the surface, and that it was Galileo in consequence who was on the right track after all.

Martin may well be right about Duhem's relation to the ecclesiastical authorities of his own day. But it is important to note that the insights Duhem finds hidden in Galileo's work are (as Martin himself goes on to point out) cosmological ones about the unity of earth and sky. Indeed, Duhem is explicit in saying that the truth Galileo was, all unknowingly, introducing was that "one form of dynamics, by means of a single set of mathematical formulae, must represent the movements of the stars . . . (and) the fall of heavy bodies" (1908, pp. 116–7). But this was not the issue between Galileo and Bellarmine. On *that* issue, the Copernican claim about the reality of the earth's motion, Duhem never qualifies his original claim that Galileo was wrong and that his critics were right. They had, in this respect, understood the limitations of the experimental method better than Galileo did (p. 13); see also 1914, p. 43. They realized (he alleges) that the hypotheses of the astronomer are not, in fact, "judgements about the nature of heavenly things and their real movements" (1908, p. 116). On this point, Duhem was entirely in agreement with them, and not with Galileo. The limited realism of the 'natural classification' later disclosed in Newtonian dynamics would undermine the simple instrumentalism they

imposed on mathematical astronomy. But it would not validate the realism of Galileo's original position.

[3] Instrumentalists might not find the theme of unification as congenial as Duhem assumes; nor would the 'natural classification' imposed by a mechanics that prescinds from causal explanation appear all that oppressive to them. It is in the end not clear what the notion of classification amounts to in the domain of mechanics (by contrast with biology or chemistry). What is being classified, if inference to unperceived entities is forbidden?

[4] He never did (so far as we know) relax his opposition to a realist construal of atoms, even in the light of the new arguments from Brownian motion which convinced Poincaré and Ostwald, and even perhaps Mach. In his last published writing, *La Science Allemande* (1915), he criticized the physics of electrons as a typical product of the *esprit géometrique* so characteristic of the German mind (pp. 131–4). He rejected the theory of relativity on the same grounds, deploring its disdain for common sense (pp. 134–9).

[5] It is worth noting that metaphysics plays a dual role for him, first as cosmology or philosophy of nature, and second, as reflection on the aims and limitations of science, i.e., as philosophy of science. The argument for the convergence of physics on a natural classification transcends the unaided resources of the physicist; it requires a 'metaphysical assertion', but one whose validity is nevertheless crucially important to Duhem's entire position. He is obviously much more comfortable with 'metaphysics' in this second sense than in the first.

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