ELSEVIER

Studies in History and Philosophy of Modern Physics 37 (2006) 738–744

Studies in History and Philosophy of Modern Physics

www.elsevier.com/locate/shpsb

Book review

M. Dorato, The software of the universe: An introduction to the history and philosophy of laws of nature, Ashgate, Aldershot, ISBN 0754639940, 2005 (174pp. £ 40.00 hardback).

Mauro Dorato's new book is subtitled "An Introduction to the History and Philosophy of Laws of Nature". This is a bit misleading: a reader previously unacquainted with any of the literature on the topic of laws of nature and related problems in the philosophy of science will find much of the book prohibitively challenging. But the book does aim for the kind of breadth and generality that one would expect from an introduction to the subject, and it serves well as a compact overview of the issues, views, arguments, and counter-arguments that have shaped the contemporary philosophical debate on laws of nature. Almost no important facet of the debate goes untouched. There are chapters or sections on: recent scholarship on the history of the notion of a law and its role in the study of nature; the characteristics of the things called "laws" in a wide range of sciences; the relations among laws, algorithmic compressibility of information, and the theory of measurement; the puzzling question of why so many laws of nature should be mathematical in form; regularity theories of laws; the universals approach to laws; the necessitarian approach to laws; skeptical eliminativism about laws; non-reductive realism about laws; the question of the supervenience of laws on non-nomic facts; the relations of laws to counterfactuals, causality, dispositions, explanation, chance, symmetry, and necessity; *ceteris paribus* clauses; the evolutionary contingency thesis and the question of biological laws; Wilhelm Dilthey and the alleged distinction between "nomothetic" sciences and "historical" ones; the question of psychophysical laws and the relation between this question and the problems of mental causation and free will; even the connection between the issue of psychophysical laws and Gibson's ecological theory of perception. This is an impressive range of topics, especially considering that they are all treated in only 174 pages. One result is that not all of them are treated with as much balance and thoroughness as one might like. Another is that readers will have it forcefully brought to their attention just how much is at stake in the philosophical debate over the nature of laws.

A refreshing thing about *The Software of the Universe* is that it attempts to avoid basing its account of laws on the standard list of philosophical intuitions about what laws must be like, and instead begins with the roles played by laws in science. Dorato writes that the "original sin" that taints many current accounts of laws is that they begin with the assumption that the generic form of a law is the qualitative universal conditional, "All Fs are G" (p. 36). Looking to the theories of physics since Newton, Dorato notes that the most uncontroversial examples of putative laws take the form of differential equations; these laws are primarily used to make calculations with the aid of initial conditions or

doi:10.1016/j.shpsb.2006.06.001

boundary conditions. He does not make much of the special features of differential equations, but he seizes on the general moral that physical laws have a sophisticated mathematical form, and that their function is to supply a method for calculating the value of one magnitude given the values of others. Thus, a law serves to provide an *algorithm* for making certain calculations, the inputs to which can come from measurements and the outputs of which can be used as predictions. This is the inspiration for the book's title: it is as if nature were a great computer, whose software encodes the same algorithms that scientists use when applying laws of nature to make predictions.[1]

Dorato eventually rejects the idea that we can really illuminate the nature of lawhood through this software metaphor (see especially pp. 46–49), but the fact that our clearest examples of laws take such a mathematical form is very important to him: since mathematically formulated laws are about relations among different magnitudes, Dorato draws the moral that laws of nature (and scientific knowledge in general) must be structural or relational (p. 67).

In the mainstream philosophical literature on laws, there is a more-or-less standard catalog of features that are supposed to set the laws of nature apart from mere accidental uniformities: universality, predictive power, necessity, counterfactual support, explanatory power, and so forth. In Chapter Three (''The Reducibility of the Laws of Nature''), Dorato goes through this catalog, and argues that it provides much less valuable guidance for the philosophical study of laws than is commonly supposed. For each item in the catalog, Dorato argues for one of three things about it: either (i) the item does not in fact accurately characterize the laws of nature, or (ii) the item characterizes laws only controversially, in that we can find a philosopher who denies that they are essential to lawhood for every philosopher who maintains that they are essential to lawhood, or else (iii) the item is indeed a feature that can be used to distinguish laws from accidental uniformities, but this feature is so closely related to lawhood itself that it gives us no foothold from which to reach an illuminating account of what lawhood really is.

Counterfactual support goes in the third category. Dorato admits (p. 84) that we can distinguish laws of nature from accidental uniformities by saying that only the former are capable of supporting counterfactuals. (He does not go into much detail about exactly what relation to counterfactuals it is supposed to be that distinguishes laws from accidental uniformities; as Lange (2000, Chapter 2) makes clear, this is a much more complicated question than it appears at first.) But he insists that if we attempt to analyze lawhood in terms of counterfactuals, we will be led into a ''vicious cycle'', since we cannot say what makes some counterfactuals true and others false without adverting to laws. For example, Lewis's (1973) account of counterfactuals analyzes the truth conditions of counterfactuals in terms of closeness of possible worlds, but (Dorato asks rhetorically), ''how can we precisely judge the *proximity* of a possible world to the actual one without considering the laws that are valid in the latter?'' (p. 84).

[1] At one point, Dorato even writes that ''[a] law of physics is nothing but an algorithm for passing from a certain set of observations of properties of a system to different observations and properties of that system'' (p. 50, emphasis added)—but from the rest of the book it is not clear whether he really means to identify laws with algorithms (which would amount to a refined version of the ''inference-ticket'' view of laws associated with e.g. Ryle) or whether this is just a moment of rhetorical excess. Dorato ends up concluding that fundamental laws are neither true nor false, and of course an algorithm is neither true nor false (pp. 114–115)—but the reasons he gives for saying that fundamental laws are neither true nor false don't have much to do with algorithms.

The second category includes causality and necessity. Many philosophers (e.g., Davidson) argue that there is a necessary connection between the concept of a law of nature and that of causality, but there is also a respectable tradition (including Anscombe, Armstrong, and Ducasse) that maintains that we can make sense of the singular causal relation independently of the notion of a law (pp. 82–83; p. 103). As for necessity, the history of philosophical disputation shows that even physical necessity (let alone some stronger grade such as logical or metaphysical necessity) is "too controversial a requirement to be invoked as a criterion of distinction between genuinely law-like propositions and accidental generalizations" (p. 82). The existence of such controversies undercut the claim that we can have secure a priori knowledge that the nature of lawhood includes such features.

Both predictive power and universality belong in the first category, though for different reasons. Predictive power might well characterize laws of nature, but since any known regularity statement can be used to make predictions, it fails to distinguish laws from accidental uniformities (p. 70). Universality, on the other hand, does not really characterize laws of nature at all, Dorato argues. He distinguishes four different things that might be meant by "universality": spatiotemporal universality, determinism, absence of *ceteris paribus* clauses, and truth. None of these senses of universality, he argues, applies to all laws of nature.

Against the claim that laws must be spatiotemporally universal, Dorato points to Kepler's laws of planetary motion, which can be formulated as applying only to the planets of our solar system (p. 73). He dismisses the suggestion that "Kepler's laws" might not really be laws of nature, on the grounds that "all manuals of physics" call them laws. One manual of physics that calls Kepler's laws "laws" is Landau and Lifshitz (1976). But unlike Dorato, Landau and Lifshitz treat Kepler's third law as a law about any two bodies subject to a Newtonian or Coulomb attraction (Landau & Lifshitz, pp. 23), and they treat Kepler's second law as a law about any particle in a central force field (Landau & Lifshitz, pp. 30–31). What they call "Kepler's laws" are thus universal in the spatiotemporal sense. So, although Landau and Lifhsitz support Dorato's claim that Kepler's laws are indeed laws, they do not thereby support his contention that there are spatiotemporally restricted laws.

As a second example, he points to the laws of chemistry, which "*emerged* only when the universe became cold enough to allow for the formation of atomic nuclei" (p. 73; emphasis Dorato's). But this example is not very convincing. Dorato insists that we must take seriously the possibility of laws that lack instances, and he raises this is a problem for Armstrong's theory of laws (pp. 99–100). If there can be laws that have no instances at all, why could not there be laws that have no instances during an initial segment of history? And if this is so, why could not the laws of chemistry be spatiotemporally universal? The fact that they have no instances prior to a certain point in time need not show that they were not laws prior to that time. Moreover, to show that a putative law is not spatiotemporally universal, it is not sufficient to show that it has no positive instances in some region of spacetime. If that were sufficient, then it would be trivial that laws need not be spatiotemporally universal: the putative law that all copper conducts electricity, for example, lacks positive instances in any region where there is no copper. But Dorato also cites recent work of Yuri Balashov arguing that sense can be made of the idea that the laws of nature evolve, and suggests that evolving laws cannot be understood as spatiotemporally universal (p. 75).

In response to the claim that laws must be universal in the sense of being true, or in the sense of lacking *ceteris paribus* clauses, Dorato rehearses familiar arguments due to Cartwright (1983). (See especially pp. 77–81.) Unfortunately, he does not acknowledge or address any of the recent objections to those arguments that have appeared in the literature (e.g., Smith (2002) and Hoefer (2003)).

Dorato concludes that the standard philosophical approach of searching for an account of lawhood that is guided by such philosophical intuitions as that laws are true, universal, counterfactual-supporting, necessary and so forth is misguided. Instead, we should be guided by close attention to what goes on in scientific practice, and to the forms that putative laws take in actual scientific theories. In Chapter Four (''What is a Law of Nature?''), he argues that two of the leading current philosophical theories of laws fail to do this, and begins presenting a view that he thinks does better.

Against the ''best systems'' account of laws due to Lewis (1973), Dorato raises some familiar objections. For example, he raises the objection that Lewis's approach makes laws depend on us and our cognitive interests. He also raises the objection that the ''Humean base'' of occurrent, non-modal, local properties which is required by Lewis's version probably does not exist as a matter of empirical fact, in the light of quantum non-locality. (He does not address the attempt by Loewer (1996) to repair the latter flaw in Lewis's view.) He also advances a new objection: Lewis's approach treats laws as members of a deductively closed axiomatic system, but in fact most scientific theories are not formulated as axiomatic systems; in fact, most of physics is not even axiomatized. Moreover, physics is not a single homogeneous block of theory; the ideal of a single axiomatic system comprising it all seems a misguided ideal. Thus, Lewis's approach ''suffers from the fatal flaw of indicating a solution to the problem of what a law of nature is that violates our requisite of adhering to scientists' practice'' (p. 95).

In reply to this objection, a defender of Lewis's approach might point out that it is not intended to give an account of the laws *of science*, but rather an account of the laws *of nature*. (Laws of science are putative laws posited by current scientific theory; laws of nature, if such there be, belong to the universe whether we are aware of them or not. Dorato discusses the distinction on pp. 68–69.) If the laws of nature are a feature of the universe independent of us and our theorizing, and it is one of the aims of science to discover the laws, then it would be a mistake to suppose that whatever the laws of nature are, they must share the features that are found among the current features of the laws of present scientific theories. To suppose otherwise, and appeal to the requirement of faithfulness to scientific practice for justification, would be rather like arguing as follows: ''All extant accounts of the evolutionary histories of particular species are sketchy and gappy; it would require a tremendous leap of faith to suppose that biology is ever going to be in a position to provide evolutionary histories complete in all details; so, if we want to remain faithful to real scientific practice, we must assume that the real evolutionary histories of particular species are themselves gappy—thus, there are no continuous lines of descent running all the way from unicellular organisms to ourselves''. The mistake here is that of failing to respect the distinction between our theorizing itself and the subject matter that we theorize about. We make this same mistake if we infer from the lack of closed axiomatic systems in current science to the conclusion that the laws of nature themselves do not comprise a closed axiomatizable system. There may be good reasons to deny that the laws of nature should be thought of as comprising such a system, but the fact that current scientific theories don't provide us with any such system is far from conclusive.

Dorato raises a similarly motivated objection to the universals account of laws due to Armstrong (1983), Dretske (1977), and Tooley (1977) (henceforth, "ADT"). If we look to real scientific practice, Dorato argues, we see that laws always pertain to abstract, idealized models, which apply to empirical phenomena only approximately. If laws are relations among universals (as ADT say they are), and these laws apply to real systems only approximately, then the universals that stand in nomological relations to one another must apply to real phenomena only approximately as well. Hence, universals must be exemplified by real objects only partly, or as a matter of degree. But the notion of "degrees of exemplification" of particulars by universals cannot be made sense of (pp. 101–102).

I am not sure that the defenders of the ADT approach cannot get around this. They might admit that science always applies laws to real phenomena by means of idealized models, and say that this is because all real natural systems involve a multitude of different particulars each exemplifying a great many different universals, each of which is involved in various laws. For this reason, the practical task of making predictions about particular systems requires us to abstract away from many of the details. Each particular could then fully exemplify each universal that it exemplifies, and the laws relating these universals to one another could hold good in every real natural system, but for practical purposes we must ignore the effects of many of the relevant laws, so that the laws we do not ignore describe a real system only approximately.

Dorato's own view of what laws are seems to be a combination of two different approaches to laws that have been popular in the recent literature. One of these is the "new instrumentalism" associated with Cartwright (1999) and Giere (1999), according to which laws should not be understood as true descriptions of reality, but rather as principles we use for constructing models, which represent real systems in an abstract, idealized, and approximate way. The second is the "dispositional essentialism" defended by Ellis (2001) and others, according to which laws describe relations among natural kinds that are essential to the identities of those kinds.

It is not entirely clear how these two ideas are supposed to fit together into a single coherent view of laws, and unfortunately Dorato nowhere gives a fully explicit statement of what his view of laws says. The closest he comes is on p. 112, where he writes that his "version of the necessitaristic thesis … considers the dispositions and the causal properties characterizing natural kinds as fundamental to the construction of the laws describing them". The idea seems to be that the universe is constituted by things falling under natural kinds, where membership in a kind confers various dispositions and causal properties on a thing, and laws of nature describing these kinds are "constructed" by us in some way that is guided by our awareness of these dispositions and causal properties, which relate to one another. The sense in which laws are "constructed" is that they hold true only in models of the universe, which are only approximately accurate representations of reality (pp. 114–115).

In defense of this view, Dorato argues that it makes sense of the fact that laws apply to real empirical systems only *ceteris paribus*: a law is valid only in an abstract and/or idealized model, which neglects some features of the real situation it is intended to represent (p. 112). Moreover, since laws describe dispositions that members of kinds possess, and dispositions are still present even in situations where they are not manifested, we should expect laws to support counterfactuals (p. 113). The view is also said to explain the sense in which laws may be said to be necessary. For laws are about the properties that characterize natural kinds, and these properties are the causal powers of natural kinds, and "[s]ince, in the context of deterministic causality, it is possible to conceive of the causes as necessary and sufficient for the effect, the corresponding causal law inherits this necessity" (p. 114). Even though laws are constructed by us, they are not mere arbitrary conventions; rather, they have empirical content, since they characterize real natural systems to some degree of approximation (p. 113). However, fundamental laws should not be regarded as either true or false, for they pertain to models rather to the real world; a model, like a map, should not be said to be either true or false, but only more or less adequate to the purposes at hand (pp. 114–115). Dorato notes that the view he defends allows for laws in the special sciences as well as in physics, and the final chapter is devoted to illustrating this.

On the one hand (according to Dorato), laws of nature are about the causal and dispositional relations among real natural kinds; these kinds are not mere conventional constructs, but correspond to real classifications in nature, and the causal powers and dispositions that characterize kinds are part of what constitutes those kinds (see especially pp. 107–112). That suggests that there are real laws out there in the world, and it is part of the job of science to find them; in that case, it would seem that the hypotheses scientists propose about them can be true or false. Either the real natural kinds really are related in the ways the hypothesis says or they are not. But on the other hand, laws (or at least "fundamental laws") are only valid in abstract and idealized models, which fit onto the world only to some degree of approximation. For this reason, they cannot be said to be true or false at all; they are true in the models that they are used to construct, but those models themselves are neither true nor false but only more or less useful. Both strands in this view have much that is appealing about them, and each has been developed and defended ingeniously by many philosophers.[2] But it is not easy to see how the two can be combined. We may hope that in future work Dorato will explain in more detail how the two strands of his view fit together. If they do add up to a single coherent view of laws, it will be a view of great interest, combining the virtues of two different leading current approaches.

References

Armstrong, D. (1983). *What is a law of nature?*. Cambridge: Cambridge University Press.

Bigelow, J., Ellis, B., & Lierse, C. (1992). The world as one of a kind: Natural necessity and laws of nature. *British Journal for the Philosophy of Science*, *43*(3), 371–388.

Bird, A. (2004). Strong necessitarianism: The nomological identity of possible worlds. *Ratio*, *17*(3), 256–276.

Cartwright, N. (1983). *How the laws of physics lie*. Oxford: Oxford University Press.

Cartwright, N. (1999). *The dappled world: A Study of the boundaries of science*. Cambridge: Cambridge University Press.

Dretske, F. (1977). Laws of nature. *Philosophy of science*, *44*, 248–268.

Ellis, B. (2001). *Scientific essentialism*. Cambridge: Cambridge University Press.

Giere, R. (1999). *Science without laws*. Chicago: University of Chicago Press.

Harre, R., & Madden, E. (1975). *Causal powers: A theory of natural necessity*. Oxford: Blackwell.

Hoefer, C. (2003). For fundamentalism. *Philosophy of Science*, *70*(5), 1401–1412.

Lewis, D. (1973). *Counterfactuals*. Cambridge, MA: Harvard University Press.

Lange, M. (2000). *Natural laws in scientific practice*. Oxford: Oxford University Press.

Landau, L., & Lifshitz, E. (1976). *Mechanics*. New York: Pergamon (transl. by J. Sykes & J. Bell).

[2]The first has been developed and defended by Harre and Madden (1975), Swoyer (1982), Bigelow, Ellis, and Lierse (1992), and Bird (2004), among others; the second by Cartwright (1999), Giere (1999), and Teller (2004), among others.

Loewer, B. (1996). Humean supervenience. *Philosophical Topics*, *24*, 101–127.
Smith, S. (2002). Violated laws, ceteris paribus clauses, and capacities. *Synthese*, *130*(2), 235–264.
Swoyer, C. (1982). The nature of natural laws. *Australasian Journal of Philosophy*, *60*(3), 203–223.
Teller, P. (2004). The law-idealization. *Philosophy of Science*, *71*(5), 730–741.
Tooley, M. (1977). The nature of laws. *Canadian Journal of Philosophy*, *7*, 667–698.

John T. Roberts
Department of Philosophy,
University of North Carolina,
Chapel Hill, NC 27403, USA
E-mail address: johnroberts@unc.edu