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Intuitions and Assumptions in the Debate over Laws of Nature

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Few concepts are as malleable as that of a law of nature. Until the seventeenth century, the phrase was typically a rhetorical device for lauding the apparent orderliness of the non-human world.[1] St. Thomas Aquinas, for example, remarks that 'if we were to enter a well-ordered house, we would gather from the order manifested in the house the notion of a governor.'[2] The orderly arrangement of objects and their powers is a testament to the wisdom and benevolence of a creator. As Aquinas goes on to say, 'the very notion of government of things in God, the ruler of the universe, has the nature of a law.'[3] In this usage, it doesn't make sense to speak of individual laws, such as the law of inertia. Nor is there any prospect of investigating nature to discover the laws it obeys.

That pre-modern talk of laws should be toothless in this way makes sense, once one considers the orthodox view that forms its backdrop, at least in the West during the medieval and late medieval periods. Very roughly, the dominant position holds that the course of events is determined by the powers that bodies have. For all their disagreements, philosophers such as Aristotle, Aquinas, and Suárez all hold a version of this view. To try to put talk of laws to any explanatory or predictive use would be to have one thought too many: there is already a metaphysical structure in place that underwrites these epistemic practices, and it appeals only to powers.[4]

The notion of a law of nature first gets something like its current sense in the seventeenth century, in the work of René Descartes. In a 1630 letter to Marin Mersenne, Descartes claims that

[1] For the origin of the concept of a law of nature, see esp. J.E. Ruby (1986), John Milton (1998), Friedrich Steinle (2002), and Sophie Roux (2011), as well as the chapters by Helen Hattab and Stathis Psillos in this volume.

[2] *Summa Theologicae* (henceforth 'ST') I q.103 a.1, in Aquinas (1945).

[3] ST I q.91 a.1.

[4] We are of course exaggerating the degree to which philosophers over this vast span of time belonged to a unified orthodoxy. Still, some of the most commonly cited heterodox thinkers—such as Nicholas of Autrecourt and Ibn Al-Ghazali—strike us as being chiefly concerned with the epistemology of powers rather than the metaphysics.

[t]he mathematical truths which you call eternal have been laid down by God and depend on him entirely no less than the rest of his creatures. Indeed to say that these truths are independent of God is to talk of him as if he were Jupiter or Saturn and to subject him to the Styx and the Fates. Please do not hesitate to assert and proclaim everywhere that it is God who has laid down these laws in nature just as a king lays down laws in his kingdom.[5]

Although Descartes is here speaking of the truths of mathematics, he extends his claim to physics in the *Principles of Philosophy*, as we shall see. For now, the crucial point is that Descartes's God stands outside of the nature his laws are to govern. Unlike the Aristotelians, Descartes does not think that nature determines its own course. It has to be directed from without.

This is the chief innovation Descartes's appropriation of 'law' talk is designed to achieve. For many Aristotelians, God plays the role of king ruling over nature, but only in a mediate way. On their view, God functions as the first and primary cause of all events, in that God is the source of all being. But creatures nevertheless have their own powers, which function as secondary causes. As Aquinas puts matters, '[t]he whole effect proceeds from [both God and the natural agent], yet in different ways, just as the whole of one and the same effect is ascribed to the instrument, and again the whole is ascribed to the principal agent.'[6] For Suárez as for Aquinas, God gets to decide what happens only in the sense that he is responsible for creating bodies and concurring with their powers.[7]

For Descartes, by contrast, God directly determines the course of events, and 'lays down' a 'law' that is not fixed by the nature of the objects that 'obey' it. Descartes bends the scholastic framework of primary and secondary causes to his novel ends. In the *Principles*, he claims that, although God is the universal and primary cause, the laws of nature are 'the secondary and particular causes of the various motions we see in particular bodies.'[8] On the scholastic view, secondary causes are needed to diversify the being that God creates. God creates and preserves things, but their precise natures are due to the secondary causes that unfold over time. That a given cat exists at all is due to God's providing it with being; but that it exists as a cat and not as a mouse or a doorstop is due to the powers and hence natures of the created beings that conspired to give it birth. Cartesian secondary causes play the same role: without them, God's effects would

[5] AT I 145/CSM III 23. References to Descartes are to the Cottingham, Stoothoff, and Murdoch translation (CSM) and to Adam and Tannery's edition of Descartes's work (AT).

[6] *Summa Contra Gentiles* in Aquinas (1945), vol. ii, 130). In the same work, Aquinas explains that 'The order of effects is according to the order of causes. Now the first of all effects is being, for all others are determinations of being. Therefore being is the proper effect of the first agent, and all other agents produce it by the power of the first agent. Furthermore secondary agents which, as it were, particularize and determine the action of the first agent, produce, as their proper effects, the other perfections which determine being' (1945, vol. ii, 119).

[7] For Suárez, see esp. *Metaphysical Disputation* 19, 1 in Suárez (1994, 281–2).

[8] AT VIIIA 62/CSM I 240.

remain undifferentiated.[9] But what plays this role is not a body with a power of its own; it is a law.

Descartes's innovation opens up the conceptual space needed to investigate particular, determinate laws that can be expressed mathematically. It would be hard to exaggerate what a departure this is from the scholastic model of scientific investigation which, for all its variations and innovations over the centuries, remained largely yoked to the model of explanation by classification in terms of powers and natural kinds.

Philosopher-scientists such as Robert Boyle complain that the Cartesian concept of *lex naturalis* is merely metaphorical: 'to speak properly, a *law* being but a *notional rule of acting according to the declared will of a superior*, it is plain that nothing but an intellectual being can be properly capable of receiving and acting by a *law*.'[10] And yet even Boyle himself was soon using the phrase.

Boyle's predicament is hardly unusual. From the start, nearly everyone who bothers to reflect much on the concept recognizes it as a legal-cum-theological metaphor that needs to be cashed out. This makes the topic importantly different from other philosophical notions such as responsibility or justice. In those cases, it does seem that pre-theoretical commitments and beliefs shape our subsequent reasoning, and put constraints on the kinds of conclusions we are willing to draw. Such is not the case, we believe, with the idea of a law of nature. That is a highly artificial notion introduced by Descartes to play a very specific role in his philosophy of physics and theology. Later thinkers will of course bend the notion to their own purposes.

If the concept of a law of nature is artificial in this way, we must be careful how we proceed. In thinking about moral responsibility, for example, it makes sense to weigh and sift through our intuitions and aim for a view that achieves the maximal degree of reflective equilibrium. One tries to preserve the strongest intuitions and achieve some kind of coherence among them. But when our intuitions and assumptions are historically conditioned in the way we believe nomological commitments are, this procedure is dubious. We must first become aware of the provenance of our intuitions: are they genuine insights, or the relics of a theological world view? Are they an artifact of (possibly outmoded) scientific practices, or simply the result of focusing on a narrow set of examples of such practices?

This chapter aims to sift through the intuitions that have guided the debate over laws of nature. It would be a fallacy, of course, to assume that an intuition's origin in an outmoded theory or world view is a mark against it. Rather, our point is that only by conducting such a genealogy can we see that these intuitions are not permanent and necessary features of everyone's conceptions of the world. They do not automatically deserve a place in our theorizing about laws; each must live or die on its own merits. We begin with the guiding intuition of Descartes's founding account, that laws govern events.

[9] For a different reading of Descartes on secondary causes, see Helen Hattab (2000) and (2007).
[10] 'A Free Inquiry into the Vulgarly Received Notion of Nature,' in Boyle (1991, 181).

1. Laws Govern

That laws in some sense 'govern' the events they are about is a feature of the earliest modern use of the phrase. For Descartes, fixing the particular facts that make up what David Lewis calls the 'Humean mosaic' does not fix the laws of nature. Even more broadly: nothing about the world of extension, not the essences of things in it or the powers of bodies, can be used to derive the laws of nature. This is because those laws have their source, not in the created world, but in God: as Descartes puts it in the *Principles of Philosophy*, '[f]rom God's immutability we can . . . know certain laws or rules of nature, which are the secondary and particular causes of the various motions we see in particular bodies.'[11] We can call this the 'top-down' view: laws are imposed, as it were, from above.

The top-down view has immediate consequences for causation: there is no way for bodies to have genuine causal powers.[12] In 1678, Ralph Cudworth makes the argument explicit when he attacks 'those mechanic Theists' who

> affect to concern the Deity as little as is possible in mundane affairs, either for fear of debasing him, and bringing him down to too mean offices, or else of subjecting him to solicitous encumberment; and for that cause would have God to contribute nothing more to the mundane system and economy, than only the first impressing of a certain quantity of motion upon the matter, and the after conserving it, according to some general laws; these men, I say, seem not very well to understand themselves in this. Forasmuch as they must of necessity, either suppose these their laws of motion execute themselves, or else be forced perpetually to concern the Deity in the immediate motion of every atom of matter throughout the universe, in order to the execution and observation of them. The former of which being a thing plainly absurd and ridiculous, and the latter, that which these philosophers themselves are extremely abhorrent from, we cannot make any other conclusion than this, that they do but unskilfully and unawares establish that very thing, which in words they oppose [i.e., the hypothesis of a plastic nature].[13]

The problem Cudworth isolates is this: there is no way for God to decree or set down a law of nature without providing the means for its enforcement. Laws cannot 'execute themselves.' Anyone who wants to retain the top-down view, Cudworth argues, faces a choice: either ratchet up the capacities of mere matter, so it can in fact understand and obey God's laws, or involve God in every causal transaction.

Although it seems not just surprising but comical from our perspective, Cudworth chooses the first option. His 'plastick nature' is a sort of 'deputy God'[14] who puts the laws into action. 'Nature,' Cudworth writes, 'is art as it were incorporated and embodied in matter, which doth not act upon it from without mechanically, but from within vitally and magically.'[15]

[11] AT VIIIA 62/CSM I 240.
[12] This argument is made at greater length in Ott (2009), ch. 9.
[13] Cudworth (1837, vol. 1, 213–14).
[14] The phrase is Jesseph's (2005).
[15] Cudworth (1837, vol. 1, 220).

Such a view is of course anathema to Cartesian mechanists, who attribute only size, shape, and motion to bodies. For Descartes himself, it seems fairly clear that his conception of laws and bodies leads to at least a kind of limited occasionalism. Although finite minds might be causes, where bodies are concerned, God is the only cause.[16] How else could the laws of nature follow from God's nature and will? As Cudworth argues, it is not as if the laws, once decreed, attain a kind of independent existence and can march about the universe directing the traffic of bodies. Hence top-down visions of laws in the modern period are tied to occasionalism.

Although top-down views have their origins in theism, they of course appear in the twentieth century in a secular context. Whether they can survive the transplant remains to be seen. Let us consider briefly the most prominent top-down view in the last forty years, which was independently devised by Fred Dretske, Michael Tooley, and David Armstrong. On the 'DTA' view, laws are relations among universals. To say that it is a law that Fs are followed by Gs is to say that the instantiation of F nomically necessitates the instantiation of G, or raises the probability of such an instantiation.[17] As Armstrong puts it, the necessitation relation is 'like an inference in nature.'[18] This view rejects the claim that the laws are fixed by the aggregate of local matters of fact and yet tries to avoid both theism and animism.

A key question here is just what DTA's nomic necessitation amounts to. It is not logical necessitation, since defenders of DTA want to maintain the contingency of the laws. In some worlds, N(F,G) holds, and in others, it doesn't. It might not hold even in a world where Fs are always coupled with Gs. Armstrong claims that we have to admit this *sui generis* notion 'in the spirit of natural piety.'[19] For DTA's Humean opponents, the well of such piety runs dry at this point. For one might wonder whether there isn't something purely stipulative about assigning the necessitation relation to universals one finds constantly conjoined.

Those attracted to top-down views have another option: non-reductivism. Perhaps the whole project of cashing out the legal-cum-theological metaphor is ill-conceived.[20] Isaac Newton famously refuses to speculate (in print, at least) on the ultimate source or underpinning of laws of nature.[21] Perhaps there is no such source; to try to understand laws as aspects of God's will or as necessitation relations among universals is to try to analyze a primitive. Although not without its attractions, this view seems to require one to adopt a strange ontological stance. We are at once asked

[16] This claim is highly controversial; for a defense, see Garber (1993) and Ott (2009). For a different take on Descartes's concept of law, see Helen Hattab's chapter in this volume. Other relevant literature is cited in Hattab's chapter.

[17] See Armstrong (1983, 88). [18] Armstrong (1997, 232).

[19] Armstrong (1983, 92). For further criticism along these lines, see esp. Barry Loewer (2004, 196 f.).

[20] John Carroll (1994) defends a non-reductive view, as does James Woodward, in his own way (this volume). Section 3 of Carroll's chapter for this volume explores the question of whether laws govern.

[21] See Newton (2004, 63 f.). For more on Newton's method, see esp. Smith (2002) and Stein (1990), as well as the chapters by Mary Domski and Stathis Psillos in this volume.

to admit laws into our ontology and prohibited from asking just where they can fit. If they are not relations among universals, what are they? And how can they make it necessary, in whatever sense, that nature take the course it does?

We emphasize the question how to understand nomic necessitation because it gets to the heart of the top-down view. All top-down views have it that the laws are actually doing something. If laws are divine volitions, then it is easy to see how this works: God, being omnipotent, forms volitions that are necessarily effective. It is much less easy to see how laws could govern anything on non-theistic top-down views: what does it mean to say, for example, that one universal necessitates the instantiation of another? It is still harder to conceive how laws could be ground-floor elements of our ontology, floating free of the bodies that 'obey' them. In the end, it is hard to escape the suspicion that the governing intuition is a holdover from the age of theism.[22] If we resist that intuition, one of the chief motivations for the top-down view falls away.

2. Laws Explain

That laws govern is only one intuitive source of support for the top-down view. Another such intuition, for Descartes as much as for DTA, is the perhaps more deeply felt intuition that laws explain their instances. In coming to know a law, one comes to know more than the parts of the mosaic the law governs: one knows *why* the mosaic is as it is. Without governing laws, there is no obvious way in which the laws can explain their instances.[23] Here again, it seems to us that what we have is not a timeless insight but a historically conditioned and indeed shifting criterion. Part of what explains that shift is a change in epistemic ambition and a desire to purge natural philosophy of its dependence on theology.

The key figures in the modern debate over explanation are George Berkeley and David Hume. Although Hume is less explicit than one would like, his treatment of causation provides a convenient starting point. On one of Hume's definitions of the term, a cause is '[a]n object, precedent and contiguous to another, and where all the objects resembling the former are plac'd in like relations of precedency and contiguity to those objects, that resemble the latter.'[24] This suggests that a law of nature will

[22] This is the view defended in Ott (2009). Others are bound to have had the same general suspicion.

[23] This is a point on which Armstrong lays considerable weight; see his (1983, chs. 2–5) and Loewer's response (2004).

[24] *A Treatise of Human Nature* Book I, Part I, section 14, in Hume 1739–40/2000, 114. Correspondingly, Hume defines necessity 'in two ways, conformable to the two definitions of *cause*, of which it makes an essential part. I place it either in the constant union and conjunction of like objects, or in the inference of the mind from the one to the other' (Book II, Part III, section 2, in Hume 1739–40/2000, 263). It is important not to be misled by Hume's gloss on the first definition of cause in the *Enquiry*. There, he says that a cause is such that 'if the first object had not been, the second never had existed' (section 7 in Hume 1748/2006, 146). David Lewis (1973, 556–7) and Peter Menzies (2014) construe this as a counterfactual analysis of causation. This would be disastrous, since counterfactual dependence is neither equivalent to,

simply be a statement of a regularity. The law does not govern anything; it merely summarizes what happens.

A crude identification of laws with regularities quickly runs into trouble. For example, some laws are stated in terms of ideal conditions and do not describe any regularities at all. Arguably, the law of gravity doesn't summarize regularities simply because it ignores the operation of other forces that are always present to some degree.[25] Conversely, there are lots of regularities—night following day, for instance—that no one would want to count among the laws. Finally, it seems obtuse to explain a given event by simply pointing to all of the other events that are similar. Regularities do not explain; they are the things to be explained.

For a more sophisticated view, we need to back up slightly and consider George Berkeley's position in *De Motu*.[26] Far more than Hume, Berkeley was sensitive to the actual practices of the scientists of his day. For Berkeley, science is not engaged in tracking causes at all, nor are laws statements of causal relations. As Berkeley puts it, it is not 'in fact the business of physics or mechanics to establish efficient causes, but only the rules of impulsions or attractions, and, in a word, the laws of motions, and from the established laws to assign the solution, not the efficient cause, of particular phenomena.'[27] These rules need not be regularities. Newton's laws, for instance, need not summarize individual events that actually happen. Instead, they can be principles or theorems that, whether alone or in combination, allow one to deduce the course of events. To explain an event is not to place it in a series of regularities. Instead, '[a] thing can be said to be explained mechanically then indeed when it is reduced to those most simple and universal principles, and shown by accurate reasoning to be in agreement and connection with them.'[28]

Hence David Lewis's contemporary 'Humeanism' would be better termed 'Berkeleyanism.' On Lewis's view, as on Hume's and Berkeley's, there is no genuine mind-independent necessity knitting together events, or the universals that figure in them (as DTA would have it). But it is Berkeley, not Hume, who identifies laws as general statements that play a role in scientific practice. And this is the key move in Lewis's theory.

If we suppose that there is, or will be, a single deductive system that best describes the world, then Lewis can define a law as a 'regularity [that is] a theorem of the best system.'[29] As we've just seen, the Humean is probably better off not making laws a subset of regularities at all but simply treating them as the theorems of the best

nor does it follow from, constant conjunction. Anne Jaap Jacobson (1986) has shown that this is not Hume's meaning; in Hume's English, his claim really is a restatement of the constant conjunction definition and not a counterfactual claim at all.

[25] Nancy Cartwright famously makes this point in (Cartwright 1980).

[26] See Psillos (2002) for a sophisticated contemporary version of the regularity theory.

[27] *De Motu* section 35 in Berkeley (1721/1975, 218).

[28] *De Motu* section 37 in Berkeley (1721/1975, 218).

[29] See Lewis (1994, 478).

system. Barry Loewer, for example, points out that Lewis's system can accommodate vacuous laws, which are regularities only in a Pickwickian sense.[30]

Lewis goes well beyond Berkeley in exploiting the metaphysics of possible worlds. And this allows him to recapture some aspects of the intuition that laws are sources of explanation. Consider the closely related issue of counterfactual support: if the law that Fs are Gs supports the counterfactual 'had x been F, it would also have been G,' there *is* a legitimate sense in which its being a law that Fs are Gs explains the actual distribution of Fs and Gs in the mosaic.

Defenders of the top-down view will object that mere regularities do not support counterfactuals: the fact that everyone in this room is wearing shoes hardly suggests that if a barefoot person were here, shoes would magically appear on her feet.[31] But if laws are not regularities (or statements of them) but instead theorems of the best system, then we can reclaim the support of counterfactuals. Any nearby world will by definition be one in which the laws hold, and hence any nearby world in which F*a* is one in which G*a* as well. Assuming a truth-functional account of conditionals, this lets us say that had *a* been F, it would also have been G. Now, the anti-Humean is still free to complain that this is not *genuine* support of the counterfactual. There is surely something bizarre, perhaps question begging, about assuming that the closest possible worlds share our laws of nature on one hand and collapsing those laws into sophisticated summaries of events on the other.

Many attacks on Lewis-style views have exactly that structure, arguing that Lewisian 'explanation' and 'counterfactual support' are mere counterfeits and not the genuine articles.[32] It is worth wondering, though, whether the defender of the best systems analysis needs to respond by recasting these concepts in a Lewisian mold. Why not simply say that they are relics of the top-down picture? Absent an argument to the effect that only the top-down, governing conception provides explanation and counterfactual support worth wanting, the Berkeleyan view's withers are unwrung.

3. Laws Explain, Round 2

The claim that laws explain in a robust sense has so far been exhibited as a star in the top-down constellation of thought. Many philosophers have felt its gravitational pull, however, without being at all attracted to the top-down view. For these thinkers, to treat the Humean mosaic as a stopping point is unacceptable. For we can sensibly ask, what explains the Humean mosaic itself? We can treat laws as mere summaries but then ask, what explains the events being summarized?

Consider the consequences of the Lewisian view for our understanding of objects and their properties. Such a position has to deny bodies and their properties any

[30] See Loewer (2004).
[31] The locus classicus for this kind of argument is Armstrong (1983, 46–51).
[32] See Loewer (2004, 189 f.) for an illuminating discussion of this dialectic.

genuine causal role. For Hume, this point is straightforward: there is nothing more to causation than constant conjunction, except perhaps the felt need to make the transition from one perception to another. For Berkeley, only God and perhaps created minds are causes. Bodies are ideas which are by their nature causally inert.

For Lewis, as for Hume and Berkeley, all properties are quiddities, that is, properties that are categorical only, with no power to change the course of events. This characterization is of course controversial, for Lewis develops his own counterfactual account of causation, which would allow properties to count as causes in that sense. But what matters here is that Lewis, just as much as Hume, denies that there are any mind-independent powers in the ordinary sense of that term.

Sydney Shoemaker famously argues that if there were quiddities, we would have no way of knowing about them. For our perceptual apparatus only tracks causal powers, and quiddities by definition escape our perceptual abilities.[33] One need not find that line of argument decisive to feel the pull of the demand for non-Berkeleyan explanation. To accommodate it, philosophers hostile to the top-down constellation are trying to turn the clock back to the time of the ancient Greeks. On this view, what makes nature take the course it does is the powers or dispositions had by the objects in it. Although the view is increasingly common in the twenty-first century, its contemporary revival can be seen in Rom Harré and E.H. Madden (1975).[34]

What notion of a 'law of nature' best fits this view? The field of candidates is broader than one might have thought. The powers view is resolutely bottom-up, and so Armstrong-style analyses, as well as anti-reductionism, are off limits. But nothing stops the proponent of powers from embracing the Berkeleyan story, or its contemporary Lewisian variant. Such a theory would hold that laws are theorems of the best axiomatization of the Humean mosaic. It's just that the powers possessed by the objects that figure in the mosaic are ultimately responsible for the mosaic itself. One would of course have to reject the counterfactual analysis of causation and other Lewisian accretions, but the core of the Berkeleyan analysis would remain intact.

There is an alternative emerging in the current literature, one with an even more ancient pedigree. In the work of Spinoza and Bacon, one finds a competing use of the term 'law.' On their views, talking about laws is a way of talking about dispositions.[35] In the contemporary scene, Brian Ellis speaks of 'a law of action . . . that describes what [a given power] does when it acts.'[36] This notion is miles away from the Cartesian theological metaphor. It might accommodate the intuition that laws explain in a robust sense while staying well clear of the top-down family of views.

[33] This is a very rough version of the argument; see Shoemaker (1980).

[34] Among the other figures in this Aristotelian renaissance are Brian Ellis, Ruth Groff, and Stephen Mumford.

[35] See Ott's chapter in this volume; Stephen Mumford's chapter also uses 'law' in something like this sense.

[36] Ellis (2010, 136).

4. Laws Enable Prediction

The logical empiricist tradition is the source of much theorizing about laws in the philosophy of science, of characteristic definitions of 'explanation' and 'law,' and of a profoundly influential theory of the relationship between science, logic, and philosophy. Any project of sifting through intuitions about laws must sieve the logical empiricist tradition in turn.

Wesley Salmon has argued that Rudolf Carnap, Moritz Schlick, Hans Reichenbach, and their fellow logical empiricists divorce scientific explanation from the pragmatic aims of prediction and control. Mary Hesse refers to the 'pragmatist criterion' for progress in science, that scientific theories and experimental methods allow for increasingly successful prediction and control.[37] On Salmon's reading, the 'Received View' associated with the logical empiricists emphasizes the pragmatist criterion to the exclusion of scientific explanation, which is treated as metaphysical. In 1988, Salmon writes,

> During the last forty years, few (if any) have voiced the opinion that the sole aims of science are to describe, predict, and control nature—that explanation falls into the domains of metaphysics or theology. It has not always been so. Twentieth century scientific philosophy arose in a philosophical context dominated by post-Hegelian and post-Kantian German Idealism. It was heavily infused with transcendental metaphysics and theology. The early logical positivists and logical empiricists saw it as part of their mission to overcome such influences.[38]

Salmon's criticisms of the 'received view' among logical empiricists reflect a broad consensus. The received view is widely accepted to be influential but untenable, although recent work aims to rehabilitate the program.[39]

[37] See Hesse (1980). The terms 'prediction' and 'control' have a long history in behaviorist psychology, beginning with John Watson and B.F. Skinner. Richardson (2006) analyzes the terms as they appear in Reichenbach's *Experience and Prediction* (1938), and Cartwright et al. (2008) contains a number of discussions of the role of prediction and control in Neurath's thought. These sources urge that prediction and control have epistemic import (in Reichenbach's case) or otherwise are guides to action (in Neurath's case). Richardson (2006): 'science will achieve objectivity . . . through a demand for epistemic control; science seeks claims that can be checked against the world and which epistemic agents can agree upon (so we can check one another)' (2006, 46). See Neurath's remark: 'Carnap . . . distinguished two languages: a "monologizing" one (phenomenalist) and an "intersubjective" (physicalist) one . . . only one language comes into question from the start, and that is the physicalist. One can learn the physicalist language from earliest childhood. If someone makes predictions and wants to check them himself, he must count on changes in the system of his senses, he must use clocks and rulers, in short, the person supposedly in isolation already makes use of the 'intersensual' and 'intersubjective' language. The forecaster of yesterday and the controller of today are, so to speak, two persons' (Neurath 1931/1983, 54–5, cited in Cat 2014).

[38] Salmon (1989, 4). Salmon's statement that the logical empiricists were aiming to overcome 'transcendental metaphysics' is only partly true. On the neo-Kantian contexts of logical empiricism, see Richardson 1998 and Friedman 1999. One might also challenge Salmon's implicit assertion that, to the logical empiricists, description, prediction, and control are distinct from scientific explanation.

[39] See, e.g., Lutz 2012. Recent work by Psillos cites the theories of causality and explanation found in Herbert Feigl, one architect of the received view.

Salmon argues that the logical empiricists attempted to answer only 'what' questions, not 'why' questions. He puts Rudolf Carnap's project of conceptual explication under this rubric: on Salmon's reading, Carnapian explication replaces a vague and unclear concept with a clear and simple one, but does not answer any deeper questions about the meaning of the concept.[40] He has similar objections to the influential view of laws in logical empiricism articulated by Carl Hempel and Paul Oppenheim: the covering law model of explanation and the associated Deductive-Nomological (D-N) model. Many classical problems (Goodman's new riddle of induction, for instance) are problems that arose for the covering law model.[41]

On Salmon's reading, Hempel's D-N model reveals only the 'logical relation between premises and conclusion' that 'shows that the former explain why the latter obtained.'[42] Once we have established the truth of the conclusion, the D-N model gives only a kind of regressive justification, which demonstrates how the conclusion follows from the laws and inferences within the model. To Salmon, the D-N model is of a piece with Carnapian explication in that it does not explain why the conclusion is true. Rather, it reveals the logical structure of the inferences used to reach that conclusion, and thus explains the reasons why the conclusion is said to be true—which is different from explaining why the conclusion *is* true.

Assuming this reading to be correct, is it true that the logical empiricists cannot account for the intuition that laws explain? Certainly, according to Salmon's own criteria, logical empiricist laws fail to explain why things happen as they do. For instance, the laws in the D-N model have a certain necessary form, but that form was only to account for the role played by the laws in inferences.[43] Thus, it is claimed, the 'Received View' does not capture our intuition that laws explain their instances.

Which 'laws,' though? One often overlooked aspect of the Received View is that it does not identify scientific laws with Cartesian laws of nature. Metaphysics generally must be divorced from our account of laws. Among the key influences on logical empiricism were the views of Ernst Mach (one wing of the Vienna Circle was the

[40] Salmon (1989, 5–6).

[41] Salmon (1989) provides an overview of these problems, of the model itself, and of the 'new consensus' on the notion of explanation in science. The 'old consensus' was reached in the heyday of logical empiricism, on the basis of Hempel and Oppenheim (1948). For critical remarks on the history presented in Salmon (1989), see below. The notion of theories as representations has been influential as well in the structuralist and semantic view of theories; see Da Costa and French (2000) for an overview.

[42] Salmon (1989, 7).

[43] On a standard reading of the 'Received View,' scientific theories must be fully axiomatized, with all results in the theory following strictly from axioms and inference rules. Lutz (2012, 77): 'In this view, a scientific theory is formalized as a set of sentences (called *theoretical sentences*) of predicate logic that contain only logical or mathematical terms and the terms of the theory (*theoretical terms*). The theoretical terms are connected to terms that refer to observable properties (*observation terms*) through sets of *correspondence rules*, sentences that contain both theoretical and observation terms. The observation terms are given a semantic interpretation, which, through the correspondence rules and theoretical sentences, restricts the possible semantic interpretations of the theoretical terms' (Carnap 1939, sec. 24; Feigl et al. 1970, 5–6). Lutz mounts a qualified defense of the Received View.

'Ernst Mach Society') and the conventionalist accounts of Henri Poincaré and Pierre Duhem. Mach argued that the laws of nature contribute to the 'economy' of science, a notion that is receiving increased attention. For Mach, the laws may promote aims we have for science—control, transparency, calculating power—but do not provide an explanatory framework that goes beyond observable phenomena.

Duhem raises a difficulty with the 'Cartesian method' in science, precisely because it combines metaphysics with physics:

> The physicist who wishes to follow [the Cartesians and atomists] can no longer use the methods proper to physics exclusively . . . Here he enters the domain of cosmology. 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 vicissitudes of that doctrine. Theories constructed by the method of the Cartesians and atomists are also condemned to infinite multiplication and to perpetual reformulation. They do not appear to be in any state to assure consensus and continual progress to science.[44]

If scientists must work out the essence of matter and of the universe before they can begin constructing a theory of physics, physics won't make much progress. The practice of physical science requires that we divorce mechanics from 'dependence on metaphysical cosmology.'

Neither Duhem nor Mach identifies scientific laws—the laws formulated in mechanics and physics—with Cartesian or Berkeleyan 'laws of nature,' and nor do most of the logical empiricists. The notion that philosophy and science should be continuous pilots some logical empiricist ships, but certainly not the notion that metaphysics and science should be.

The question whether laws on the Received View explain their instances cannot be answered, then, without also answering the question of whether the laws in question are laws of nature, or scientific laws. If the latter, then there is a question whether the laws employed by the Received View even were intended to be fit for very many of the roles Descartes, Berkeley, and the others wanted laws to play. Since an explicit aim of many logical empiricist philosophers was to separate metaphysics from science, it may be wise to take them at their word, and to concede that the logical empiricist position was never intended to capture the Cartesian or Berkeleyan intuitions about the laws of nature.

The more interesting question, then, is: What is the significance for the philosophy of science of the turn away from metaphysical laws of nature and toward scientific laws? On Salmon's account, the logical empiricists cannot use laws to explain their instances. But Hempel and Oppenheim focus the D-N model precisely on *explanation*. What seems to be at stake, then, are criteria of adequacy for 'explanation.' Apparently, behind Salmon's objections is the conception that laws should explain

[44] Duhem (1996/1917, 233–4).

why events take place, not just by revealing the structure and source of law-governed inferences, but by explaining why the laws are the source of true conclusions about events. If so, Salmon is requiring that an account of laws must satisfy what some logical empiricists would take to be a metaphysical notion of the truth of those laws.

We may well ask, then, whether Salmon and the Received View are operating with the same notions of truth or of explanation in the first place. Salmon is correct that banishing metaphysics and 'theology' from philosophical reasoning about the laws of nature was a motivation for some logical empiricists. Salmon does not account for the influence of conventionalism, neo-Kantianism, and pragmatism on logical empiricism, an influence that has been tracked in detail by subsequent scholars in the history of philosophy of science. We might trace the relative neglect of these sources to the continuing influence of Willard van Orman Quine's 'Two Dogmas of Empiricism,' starring Carnap as the lead dogmatic empiricist. Quine urged that abandoning logical empiricism would result in a turn toward pragmatism.[45] The implicit assertion that logical empiricism and pragmatism are at odds with each other has been challenged in recent work.[46]

What changes would be wrought to our account of the Received View if we were to interpret their account of law-governed explanation, and of explication, as motivated by the separation of Cartesian metaphysics from physics, and by the view that laws need not be true to explain?

5. Laws Are Universal

There is an enduring intuition that laws of nature must be universal. To paraphrase Sellars, since laws explain nature, they should explain why things, in the broadest possible sense, happen the way they do, in the broadest possible sense. Pragmatist and conventionalist currents in the philosophy of science and in metaphysics challenge this intuition—and some of these currents are found within the logical empiricist tradition itself.

Nancy Cartwright's *Why the Laws of Physics Lie*, and her work since, has established an enduring challenge to the intuition that laws are universal statements that hold without exception.[47] It may come as a surprise, then, to learn that Cartwright locates a source of her own view within the logical empiricist tradition. One way to read Cartwright's 'dappled world' is that, in it, prediction and control are local phenomena. Cartwright cites her 'own hero, Otto Neurath': 'Those who

[45] Quine (1951), 20; see Richardson 2007 for a critical response.

[46] Richardson (2007) and Misak (2016) have analyzed critically this interpretation of the history of logical empiricism and of the philosophy of science more generally. Creath (e.g., 1995) has challenged the thesis that Quine and Carnap are as far apart as some philosophers allege.

[47] In their chapter in this volume, Cartwright and Merlussi argue that all of the views on laws currently on offer are consistent with the rejection of universality.

stay exclusively with the present will very soon only be able to understand the past.'[48] Cartwright continues:

> Just as the science of mechanics provides the builder of machines with information about machines that have never been constructed, so too the social sciences can provide the social engineer with information about economic orders that have never been realized. The idea is that we must learn about the basic capacities of the components; then we can arrange them to elicit the regularities that we want to see.[49]

By learning about the capacities of components of systems, we may be able to control, locally, the outcomes of the mechanisms we employ or observe. But there is no ultimate system, no universal set of laws that govern the workings of such systems.

With Cartwright and Neurath, we move away, not only from the intuition that laws explain, but also from the view that laws are universal and not local. The notion that explanation is local has found expression in the powers view discussed above, but also in the new concern, in philosophy of biology, with explanation via mechanisms.[50]

Frank Ramsey, who proposed a canonical version of the Best System Analysis (BSA), and Hilary Putnam, who proposed the no miracles argument for scientific realism, created now standard positions on the laws of nature that were influenced by pragmatism. Putnam's and Ramsey's accounts are what Cohen and Callender call 'non-governing' accounts of laws, according to which 'there are genuine laws of nature, but . . . they do not govern or produce the events of the world. The mosaic of events displays certain patterns, and it is in the features of some of these patterns that we find laws.'[51] On this view, the laws are embedded in the mosaic—as Earman and Roberts (2005) put it, the laws supervene on the 'humble facts.'

If the system in question is embedded in the Humean mosaic, there might be various ways to formulate the intuition that the laws of the system are universal. For the laws to be universal, they would need to hold independently of ceteris paribus clauses. Such clauses formulate cases in which the background conditions might vary (if you strike a match, it will light, unless the match is wet). Or, ceteris paribus clauses may specify properties of objects that make the laws fail to hold (if you strike a match, it will light, unless the match's head is made of clay).[52]

[48] Trans. by Cartwright from the citation in Nemeth (1981, 51).

[49] Cartwright (1999, 124).

[50] See, e.g., Machamer et al. (2000) and Bechtel and Abrahamsen (2005). A growing body of work challenges the universality of laws. Leuridan (2010) gives an illuminating analysis of the philosophical import of recent work on mechanisms and on non-universal laws. A special issue of *Philosophy of Science* from 1997 focused work questioning the universality of laws in biology, including essays by Beatty, Brandon, and Sober. Christie (1994) cites evidence from chemistry, and from chemical practice, to argue against universal laws in chemistry. Beed and Beed (2000) make a similar case for the social sciences. Woodward (1992, 2003) and others argue for mechanisms as part of a larger account of complex systems. Mitchell (2000) argues explicitly for pragmatism concerning the laws of nature, and against the universalist conception.

[51] Cohen and Callender (2009, 1).

[52] The account of laws according to which they are the invariants of scientific theories is found in Eugene Wigner, James Woodward, and Emmy Noether. For a recent defense, see Woodward's chapter in

For Earman and Roberts, the 'humble facts' are the non-nomic initial conditions and boundary conditions of a physical problem. The laws, in turn, are used to derive differential equations that determine the evolution of a physical system given the initial and boundary conditions. On their view, the differential equations are not different in kind from the boundary conditions.[53] The equations describing the evolution of the system are not different in kind from physical facts about the system. Thus, in one way, the laws are 'universal' by default. There are no background or initial conditions that would make the laws fail to hold, because the laws simply formulate the regularities that hold of the mosaic.

However, the laws of the BSA are not universal in the sense specified by Hempel, namely, that their terms are universally quantified in all possible contexts. The claim 'For all observed x in the mosaic, y is true' does not imply that 'For all x, y is true.' Certainly, the BSA is intended to use laws for prediction, but it does not have the consequence that the universal quantification works for all possible objects or phenomena, without taking account of the observed facts. Thus, Lewis's and Ramsey's accounts leave room for distinct ways of reading the Best Systems Analysis as a theory of 'universal' laws.[54]

6. Conclusion

Three central and related points have emerged so far. Together, they should make us question our methods and assumptions before entering into the scrum.

First, Salmon's critique of the logical empiricist tradition represents, as far as we can tell, the most common attitude among philosophers. Our assessment of Salmon's critique suggests that the logical empiricists are not engaged in the project Salmon takes them to be. He assumes they are trying to explain and justify the sorts of laws that figure in the metaphysical tradition, from Descartes to Berkeley, and then complains when they fail. But that failure might make us wonder whether the logical empiricists made the attempt in the first place. Have they missed the target, or were they aiming elsewhere?

What's distinctive of their approach, we argue, is the attempt to sever theorizing about scientific practice from metaphysical concepts and debates. If the physicist

this volume. For more on Emmy Noether's arguments on conservation laws and symmetry principles, see Brading (2001). Woodward's account focuses on the *independence* of laws from certain initial conditions. Woodward argues that our ability to divorce lawlike statements from initial conditions via the identification of relevant symmetries is fundamental to reasoning about the laws of nature. Here, Woodward shares a methodological approach with Earman and Roberts's (2005) 'New Characterization of the Humean Base,' of looking for ways to divorce laws from their initial and boundary conditions (2005, 13–17).

[53] Earman and Roberts (2005, 14–15).

[54] Cohen and Callender (2009) propose a 'better best systems analysis.' In this volume, Massimi unites the best systems analysis with the perspectival realism proposed by Ron Giere, to argue for a perspectival best systems analysis. Massimi's system has the advantage that it proposes resolutions to philosophical problems and paradoxes long associated with the history of science.

declines to 'enter the domain of cosmology,' she will hardly be bothered by any slings and arrows that are flung from that domain. If this is right, then the logical empiricist tradition is due for a re-evaluation.

The cleavage between laws as they actually figure in scientific practice and what we might call 'the laws of the philosophers' suggests a second distinction: that between the causal story involved in any given interaction and the philosophical account of the laws that are concerned in that interaction. For instance, as we argued above, the powers theorist is perfectly able to endorse any of a wide array of stories about laws, from Best Systems Analyses to regularity theories; only top-down views are off limits. This suggests that the powers theory is not, in and of itself, competing for quite the same territory as the other theories of laws. An account of powers can close off some stories about laws; but that account need not itself choose one of the remaining competitors.

To see this in practice, consider that the powers account is typically taken as a competitor to Humean supervenience accounts.[55] It is quite right, of course, that the powers theorist is hostile to the project of doing away with mind-independent causal connections, or substituting Lewisian ones in their stead. But nothing prevents the powers theorist from hijacking a Best Systems Analysis and yoking it to her own ontology. Indeed, the powers theorist might retain something of the flavor of the logical empiricist view, and insist that scientific laws are a different kettle of fish altogether.

These two reflections suggest a third: that a degree of skepticism is warranted when positions on laws of nature are attacked for not being faithful to this or that alleged desideratum. What features or facts one selects as 'data,' or which constraints or criteria one sees as essential to a theory of laws, has as much to do with the tradition in which one is operating as anything else. From some points of view, universality is absolutely non-negotiable; from others, it's a fantasy, one that might well be rooted in an early modern theological approach that we see in Descartes. Equally, from one vantage point, it's simply obvious that laws govern, and the task is to say how they do so. From another, that thought is conditioned by a theological tradition we would do well to slough off permanently.

The conception of a 'law of nature' is a human product. It was created to play a role in natural philosophy, in the Cartesian tradition. In light of this, philosophers and scientists must sort out what they mean by a law of nature before evaluating rival theories and approaches. If one's conception of the laws of nature is yoked to metaphysical notions of truth and explanation, that connection must be made explicit and defended. If, on the other hand, one's aim is to disentangle laws from truth or from explanation, that must be stated and defended as well.

If philosophers do not make such assumptions, intuitions, and methodological commitments clear, then it will be impossible to identify the source of disagreement

[55] See, e.g., Loewer's excellent (2004, 200 f.).

in debates about the laws of nature. Are the conflicts rooted in disagreement about the conclusions reached, or do the background commitments of the combatants block any resolution to the dispute in principle or in practice?[56]

We are far from embracing a nihilistic relativism about laws. We firmly believe there are facts of the matter to be discovered. The trick is to be sure we are arguing about the same thing. And not to allow our intuitions to exercise their influence unexamined.

[56] Do we reach a standoff reminiscent of Wittgenstein's *On Certainty*, in which each gives her reasons, but no reason can end the debate? (Wittgenstein 1972; see Kusch 2016 for a discussion of epistemic relativism and skepticism in this context.)