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Powerful Properties, Powerless Laws

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1. Introduction

In debates about the fundamental ontology and the laws of nature, two opposing metaphysical pictures loom large: the Humean picture and the anti-Humean picture. When it comes to the fundamental ontology—the most basic stuff out of which everything else is made—Humeans defend an austere fundamental ontology. They claim that, at bottom, the world is made up of only categorical (non-modal) properties distributed through spacetime. Anti-Humeans, on the other hand, defend a rich fundamental ontology. They claim that, at bottom, the world includes at least some modal entities. One example of a modal entity is a fundamental dispositional property, called a *potency*. I will have much more to say about potencies below. When it comes to the laws of nature, the most popular Humean account is the *Best System Account* (BSA). According to the BSA, laws are not fundamental, and they do not govern the world but merely systematize it. By contrast, according to several anti-Humean accounts, laws have metaphysical power because they govern the world.

I argue that the best scientific package is anti-Humean in its ontology, but Humean in its laws. This is because potencies and the best system account of laws complement each other surprisingly well. If there are potencies, then the BSA is the most plausible account of the laws of nature. Conversely, if the BSA is the correct theory of laws, then formulating the laws in terms of potencies rather than categorical properties avoids three serious objections: the mismatch objection, the impoverished world objection, and the metaphysical 'oomph' objection. I argue that combining anti-Humean properties with Humean laws into a *Potency-Best System Account of Laws* is a powerful and science-friendly account—something that people on both sides should be able to appreciate.

2. The Categorical Best System Account

I will begin by presenting the traditional, categorical best system account of the laws of nature, made famous by David Lewis,[1] which consists of two pieces. The first is a fundamental ontology of categorical properties and spatiotemporal relations, referred to by Lewis as the *Humean mosaic*.[2]

The second piece of Lewis's best system is a set of true statements that summarize and systematize the distribution of those properties and relations. These statements often take the form of universal generalizations, such as '$F = ma$.' Systematizations can be simple, informative, both, or neither. For instance, a long list of every property's instantiation—one mass at (t_1, x_1, y_1, z_1), one charge at (t_2, x_2, y_2, z_2), etc.—is informative, but not very simple, while the single statement, "all instantiations of mass move closer together throughout time, all else equal," is simple, but not very informative. Then, Lewis postulates that the basic laws of nature are the axioms of the systematization that best balances simplicity and informativeness.[3,4]

Lewis adds the further constraint that the laws reference only the *perfectly natural* properties and relations. Perfect naturalness is a primitive feature of Lewis's theory and corresponds roughly to other authors' notions of universals, sparse properties, or elite properties (see Armstrong 1978 and Lewis 1983a). Lewis has in mind properties like mass and charge when he talks of perfectly natural properties, though below I will question whether he is justified in assuming that the properties of our basic physics match up with the perfectly natural properties. To see why naturalness is necessary for Lewis, consider 'F,' the predicate which stands for the property applying

[1] This account is often called the 'MRL' account for its early proponents, Mill, Ramsey, and Lewis. The account is developed further and in different directions by various authors such as Helen Beebee (2000), Barry Loewer (2007), Markus Schrenk (2008), and Jonathan Cohen and Craig Callender (2009).

[2] The crucial idea behind a fundamental ontology is a metaphysical one: what is the minimum amount of stuff needed to guarantee the existence of the entire world? (A useful, much-used metaphor is to consider what God would have to create, in order to thereby create the entire universe.) For instance, suppose a table is nothing over and above atoms arranged table-wise. Then, the atoms are more fundamental than the table, and the existence of the atoms, along with their properties and relations, is sufficient for the table's existence. Thus, when the Humean postulates a fundamental ontology of purely categorical (non-modal) properties and relations in spacetime, she has to show how all the other features of the world, such as the laws of nature (but also tables, minds, causation, etc.) depend upon that ontology. There is a vast and fascinating literature on fundamentality and the related notion of ground, but the particular details will not be relevant here. For more, see Bennett (2004), Koslicki (2012), and Schaffer (2009).

[3] Throughout this chapter, I will refer to such *scientifically fundamental* laws as 'basic laws,' and I will reserve the term 'fundamental' for those things that are *ontologically* basic. Note that according to the best system account, the basic laws are not fundamental, because they supervene (or depend) on the fundamental Humean mosaic.

[4] Two caveats: First, if the world is chancy, then Lewis argues the best system will have to balance simplicity, informativeness, and *fit*. In this chapter, I will bracket all issues relating to chance, treating the world as a deterministic system. For more, see Lewis (1983a, 1994) and Elga (2004). Second, Lewis hopes that one system will emerge as the clear winner, though he also tells us what to do if two or more theories tie for the best in balancing simplicity and informativeness, but these details will not be relevant here.

to all and only objects at worlds where a given systematization holds. Then, the laws of the universe could be summarized by the axiom: '$(\forall x)Fx$.' Since this simple and (arguably) informative axiom would be 'best,' it also would trivialize the BSA. Therefore, Lewis stipulates the perfect naturalness constraint, eliminating such an axiom from eligibility.[5]

2.1. Science-Friendliness

In the scientific quest to discover the laws of nature, scientists routinely look for simple formulas that predict a wide range of phenomena. This emphasis on simplicity and informativeness is mirrored in the desiderata for the best system account, which lends the BSA additional credibility. According to Cohen and Callender:

> [The best system account] states that laws are the generalizations that result from a trade-off between the competing virtues of simplicity and informativeness. Scientists certainly see themselves as engaged in the project of finding such generalizations. . . . [I]t is clear especially since Newton that scientists have sought general but simple principles applicable to systems with very general features. Virtually every science textbook contains frequent appeal to simple principles that cover a vast array of phenomena in the field. Even philosophers skeptical of laws recognize that scientific theorizing is a process of carefully balancing simplicity and strength (e.g. Cartwright, 1983, 144). And in many cases the result of this process is a set of fundamental principles [basic laws] that are taken to describe the essence of a theory.
>
> (Cohen and Callender 2009, 3)

But, as Lewis pointed out, simplicity and informativeness are only well-defined *relative* to a set of predicates. Since scientists do not have direct access to these perfectly natural properties, they postulate the existence of properties based on how well those properties systematize. What then, is the systematization *of*? Ned Hall articulates a popular way of thinking about the project that I endorse:

> The primary aim of physics—its first order of business, as it were—is to account for motions, or more generally for change of spatial configurations of things over time. Put another way, there is one Fundamental Why-Question for physics: Why are things located where they are, when they are? (Hall 2010, 29)[6]

On this picture, particle trajectories through spacetime are the explananda, the phenomena to be predicted or captured by a theory. And, scientific theories include references to properties. So, the question naturally arises: how do the properties referenced by these theories relate to Lewis's perfectly natural properties? I take up this question in the next section and argue that the relation is a tenuous one.

[5] Not all defenders of the best system account accept perfectly natural properties—see, for instance, Loewer (2007) and Cohen and Callender (2009). For an illuminating discussion of several such accounts, see Eddon and Meacham (2015).

[6] It is not clear whether Hall endorses this way of thinking about physics, but his perspicuous presentation of the view is worth repeating here.

2.2. The Mismatch Objection

While the best system account is faithful to scientists' concern with simplicity and informativeness, its insistence on a fundamental ontology of perfectly natural, categorical properties makes it vulnerable to a 'mismatch' objection.[7] Suppose, the argument goes, that our best scientists have arrived at a very simple, very informative final theory of everything (TOE). But, suppose further, that this theory is formulated in terms which reference properties that differ from Lewis's perfectly natural properties—call them 'TOE' properties. We can easily imagine that in such a situation, the best system (i.e. the simplest), most informative system *restricted to terms that pick out perfectly natural properties*, is intuitively much less simple and/or much less informative than the TOE, which is not so restricted.

To see why, consider again Hall's characterization of the TOE: *The theory that summarizes, as simply and informatively as possible, the trajectories of particles.* In order to do that, scientists appeal to the properties that make for the best systematization, in this case, the TOE properties, and what they have straightforward access to is the trajectories (Figure 4.1).

But, if Lewis is right, then the real laws of nature do not systematize the trajectories, but rather, the distribution of perfectly natural properties in spacetime (Figure 4.2).

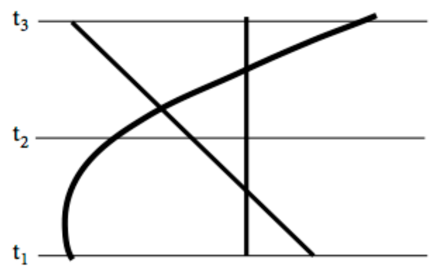

Figure 4.1. Trajectories of particles through spacetime

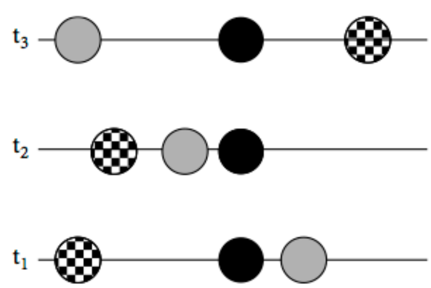

Figure 4.2. Distribution of perfectly natural properties

[7] Bas van Fraassen (1989, 53) introduces a version of this objection. Lewis (2009) acknowledges this version, but does little to address it. See also Loewer (2007), Cohen and Callender (2009), and Hall (2010).

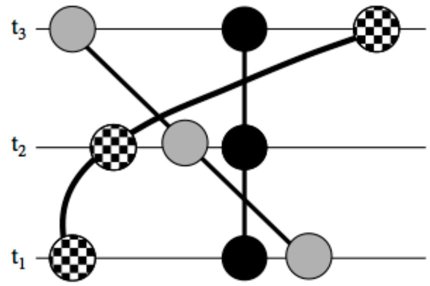

Figure 4.3. The BSA hopes for a match between the TOE properties, which figure in theories of trajectories, and the perfectly natural properties, which figure in the BSA

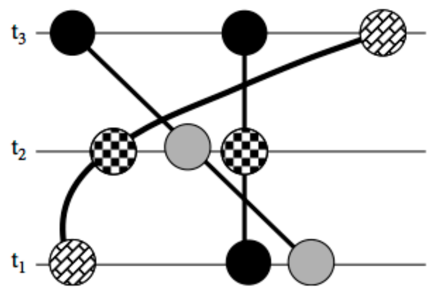

Figure 4.4. But, a mismatch is not only possible, but also undetectable. One pattern of trajectories is compatible with vastly many different distributions of categorical properties

Lewis hopes that the systematization of the perfectly natural properties matches up with the trajectories. However, there is no guarantee—not even a probabilistic argument—that they match up in just the right way. Furthermore, two worlds with the very same particle trajectories, and thus the same TOE laws and TOE properties, on the Humean view, could have radically different distributions of categorical properties (Figures 4.3 and 4.4).

In the two scenarios in Figures 4.3 and 4.4, the TOE yields the same laws while the BSA yields different laws. This is because categorical properties bear no necessary connections to the behavior of the objects that instantiate them. Thus, for every world in which the TOE does match the BSA, there are many, many more worlds in which it does not, and there is mismatch.

What is even worse for the Humean, is that when there is such a mismatch, it seems that the simple, informative TOE is a better candidate for the real laws of nature than the complicated, uninformative BSA. After all, on the Humean picture, the laws are supervenient entities, postulated to capture actual scientific practice in a way that is faithful to the Humean picture of the world. The introduction of perfect naturalness is merely a way to deal with the triviality objection. We then have two competing intuitions. On the one hand, it is plausible that the laws of nature systematize the distribution of the fundamental properties. On the other hand, it seems that the laws of nature should systematize particle trajectories as simply and informatively as possible.

What the mismatch objection shows is that the Humean is not entitled to demand *both*. And, if our theory of laws is motivated by actual, scientific practice, we ought to prefer the TOE to the BSA—a serious strike against the categorical-BSA.

It is important to see why the mismatch objection isn't just a skeptical argument. Of course, there is no guarantee, and indeed, there should be no such guarantee, that our best science will describe the actual world perfectly. The world can always conspire against us to make good theories seem bad, and vice versa. However, this objection goes further by alleging that Lewis's best system gets things wrong, even granting perfect knowledge of the categorical base. This is because the distribution of perfectly natural properties might be quite complicated to systematize, as in Figure 4.4., while a systematization of particle trajectories—even if that systematization is in terms of non-perfectly natural properties—could be very simple and informative. Since the Lewisian places so much importance on simplicity, informativeness, and science-friendliness, while de-emphasizing extraneous metaphysical commitments, by the Lewisian's own lights, the TOE properties begin to look like better candidates than the perfectly natural properties for formulating the laws of nature.

2.3. Impoverished Worlds Objection

One well-known objection to the best system account arises for laws of nature in impoverished worlds (see, for example, Tooley 1977, Carroll 1994, and Beebee 2000). Consider, for example, a world in which there is only one particle, which happens to instantiate mass.[8] Such a particle will behave inertially for all time. Therefore, according to the BSA, there is one law at this world: all massive particles travel inertially for all time. But, intuitively, the law should say that massive particles attract other massive particles and behave inertially only in the absence of other massive particles. Ordinary counterfactuals lend support to this objection. If that particle were in the presence of one other particle which happened to be massive, it would not behave inertially.

Defenders of the BSA try to minimize the force of this objection by pointing out that our world is not impoverished (see, for example, Loewer 2007 and Hall 2010). And intuitions about worlds like ours matter more than our intuitions about other worlds. If the BSA gave the wrong result for the *actual* world, that would be a problem, but it only does so for other, exotic worlds. Another response is to distinguish between statements that are *laws in* other worlds and statements that are merely *true of* other worlds. The statements that systematize world *A* give the laws that are *laws in A*. Statements that are laws of other worlds may be *true of A*, even if they are not *laws in A*. So, the Humean can say that the statement 'massive particles attract one another, all else equal' is *true of* the impoverished world, even though it is not a *law in* that world.

[8] Here, and throughout the chapter, I use toy-physics examples. The behavior of Newtonian mass is easier to understand than quantum mechanics, though I have every reason to think my arguments work just as well with Bohmian mechanics, for example.

These responses help, but are far from satisfactory. While I care *more* about the laws at the actual world than at impoverished worlds, as a metaphysician I care about the laws at impoverished worlds too. A good theory of lawhood should give the right results for what the laws are in *any* world. As for the *law in/true of* distinction, it is of no help with counterfactuals. The impoverished world will have many different, incompatible statements true of it, and if we relied on them for counterfactuals, they would yield different counterfactuals. But, surely there is a fact of the matter about what the massive particle would do, were it to encounter another massive particle. The Humean is not able to accommodate that fact with a straightforward appeal to the laws. I argue below that the dispositionalist can.

2.4. Metaphysical Oomph Objection

Some philosophers, such as Fred Dretske, Michael Tooley, David Armstrong, and Tim Maudlin, argue that the laws have very important metaphysical work to do, and the categorical-BSA is not equipped for such work. According to this objection, some parts of the world are fundamentally *powerful* (see Dretske 1977, Tooley 1977, Armstrong 1983, and Maudlin 2007). The laws provide a kind of 'oomph' that governs, or produces, the behavior of the particles in the world. But other philosophers, such as Barry Loewer and Jenann Ismael (personal communication), think that intuitions about governance and production need not be taken seriously. One reason is because these notions are often obscure or mysterious. Thus, before I argue that the categorical-BSA is ill-equipped to account for governance or production, I would like to make these notions more precise. I suggest that metaphysical power is best thought of as *dynamic, metaphysical dependence*.

There are many entities in the actual world and they are related by a variety of metaphysical dependence relations. For instance, the following are plausible candidates for such dependence:

- A mountain is related to the atoms that compose it by the metaphysical dependence relation of constitution—the mountain depends on the atoms.
- The truth of the proposition that it is raining is related to the fact that it is raining by the metaphysical dependence relation of truthmaking—the true proposition depends on the fact.
- A mind is related to a brain by the metaphysical dependence relation of realization—the mind depends on the brain.

Suppose the world does contain dynamic, metaphysical power. This power is best captured by the metaphysical dependence relations of governance and production. Both relate entities or events at one time to entities or events at an earlier time. Governance does so via the laws, while production does so via dispositional properties.

Governance: The behavior of entities or events (at least partly) dynamically, metaphysically depends on the laws of nature.

Production: The behavior of entities or events (at least partly) dynamically, metaphysically depends on properties.

Note that the ontology of the categorical-BSA does acknowledge some metaphysical dependence relations. For instance, the laws of nature, as statements that systematize the distribution of properties in spacetime, metaphysically depend on the distribution of properties in spacetime. However, the ontology of the categorical-BSA does not support any kind of *dynamic* metaphysical dependence. This is because the fundamental base includes the entire Humean mosaic of categorical properties: past, present, and future, with no metaphysical dependence relations between states at different times. Of course, from the laws and the state at a time, the Humean can *predict* the future states, but the laws are themselves metaphysically derived from those future states, so there can be no dynamic metaphysical dependence. This lack of powers should come as no surprise to the defender of the categorical-BSA, since the Humean mosaic is postulated with this requirement explicitly in mind (see Lewis 1983a, Beebee 2000, Loewer 2007, Cohen and Callender 2009, and Bird 2007a).

It is no use for the Humean to appeal to a theory of causation. Since Humean causation ultimately depends on the Humean mosaic, it does not exhibit dynamic metaphysical dependence either. For the Humean, nothing short of the entire mosaic is sufficient to guarantee the entire mosaic. Some Humeans argue that their account of causation can explain our experience of macroscopic 'oomph.'[9] But Humean causation is a higher-order phenomenon, and does nothing to accommodate production (or governance) at the fundamental level. More importantly, the *experience* of production is different from the intuition that the world, fundamentally, is produced.

The intuition that there is production (or governance), fundamentally, in the world, is strong enough that any theory which denies it is biting a substantial bullet. Helen Beebee (2000, 593) argues that even so, "the Ramsey–Lewis view does justice to enough of our intuitions about the laws of nature to be a viable alternative." That may be, but I think that the defender of the BSA can do even better. By exchanging purely categorical properties for potencies, as I argue we should, the best system account of laws *can* accommodate our intuition that there is fundamental, metaphysical 'oomph' in our world.

3. Potencies: Fundamental Dispositional Properties

Many philosophers argue that the fundamental properties are *dispositional.*[10] Dispositional properties are necessarily connected to the behavior of the objects that instantiate them. Take, for instance, the property of having mass. If mass is *categorical*, then massive objects in different possible worlds can behave very differently, attracting

[9] In personal communications, David Albert, Jenann Ismael, and Barry Loewer take this experience as illusory—or at least reducible to something that does not include 'oomph.'

[10] See, for example, Ellis and Lierse (1994), Mumford (1998), Bird (2007a), and Jacobs (2011).

each other in some worlds (like ours), repelling each other in other worlds, and neither attracting nor repelling in still others. However, if mass is *dispositional* in the way I think it is, then the property of having mass is necessarily connected to the behavior of the objects that instantiate it. Thus, any massive object, in any world, is disposed to attract other massive objects.[11]

In what follows, I will rely on Alexander Bird's (2007a) characterization of fundamental dispositional properties, as presented in *Nature's Metaphysics*, though my conclusions should generalize to many other dispositionalist accounts. My account of potency-BSA can be thought of as elaborating on Bird's suggestion that it is possible to derive universal generalizations from potencies.[12] Since dispositions can exist at any level (fragile vases or massy electrons) and for a wide variety of properties, as gerrymandered as you like, Bird (2007a, 45) introduces a new term, *potency*, that is defined as follows:

Potency: A fundamental, sparse property with a dispositional essence.[13]

Potencies can be thought of as dispositional versions of Lewis's perfectly natural properties. They are fundamental, so they are not made up out of anything else—they are on the 'ground floor' of the world.[14] They are sparse, and as I will argue below, correspond to the scientific kinds that appear in our best physical theories. The dispositional essence of a potency is the necessary connection between the property and the behavior of objects that instantiate it.[15,16]

11 I will set aside the interesting and important debate about whether the categorical/dispositional distinction can be successfully drawn, or whether all properties must be both qualitative and dispositional. For more on this, see Martin and Heil (1999), and Jacobs (2011).

12 Bird argues that the regularities of a best system account can be derived from potencies via the following entailment: $\Box(\forall x)(Px \leftrightarrow (Sx \mathbin{\Box\!\!\rightarrow} Mx))$ entails $(\forall x)(Px\&Sx) \rightarrow Mx))$, where P is a potency, S is a stimulus condition, and M is a manifestation. Unfortunately, Bird does not elaborate on what it is that metaphysically grounds the biconditional. I do not rely on counterfactuals in deriving the laws of nature from potencies, and doubt whether Bird's formulation succeeds. Nevertheless, I take my account to be very much in the same spirit as Bird's. I fill in the details of just what a potency best system account should look like, and why we should prefer it.

13 Though the arguments in this chapter won't depend on the answer, another interesting question is whether to treat the potencies of 1 kg, 2 kg, etc., as one (determinable) potency with infinitely many determinates, or as an infinite number of different potencies. I am inclined to agree with Jessica Wilson (2010), who argues that the fundamental properties are best thought of as determinables. Additionally, I will address only briefly the very complex issues of component forces.

14 While some, for example G. K. Chesterton, have objected to the coherence of fundamental dispositions, the literature is full of excellent replies, and I need not repeat those arguments here. For a particularly nice reply, see Bird (2007b).

15 Several defenders of dispositional properties have moved from talk of dispositions and stimulus conditions (situations) to *mutual manifestation partners*. Thus, rather than think of one instance of mass as the disposition and another instance of mass as the stimulus condition (situation), it is more accurate to think of both instantiations of mass as participating equally in the interaction. When two masses are near each other, they both manifest mutual repulsion. Singling out one as the disposition and the other as stimulus is merely an artifact of our particular interests. I think this is a promising idea and my conclusions in this chapter should carry over to such a picture.

16 Schrenk (2010) argues that the connections between these properties cannot be necessary because other conditions—namely, antidotes—can always intervene, altering the dynamic dependence. Thus, a more

Three things to note. First, even though the potencies are metaphysically more fundamental than the behavior of the particles that instantiate them, the behavior of particles across worlds is sufficient to individuate potencies (i.e. no potencies have the same essential dispositions). Second, while this connection entails certain counterfactuals (how objects *would* behave in different circumstances), those counterfactuals depend upon the nature of the particles involved, how they are arranged, and what potencies they instantiate, so I reject any attempt to analyze potencies in terms of counterfactuals. The metaphysical direction of explanation runs the other way. Third, potencies are purely deterministic. I see no reason why propensities—chancy dispositional properties—could not be integrated into the potency-BSA, but I leave that development for a future paper.

A potency's dispositional essence, plus the stimulus condition or external situation, determines the behavior of any particle instantiating it. I will turn to the question of *how* this determination works in section 4.4. Sometimes this behavior is the instantiation of a further potency, as when a moving charge induces a magnetic field, and sometimes this behavior is simply a modified trajectory through space(time).[17]

3.1. Potencies are Science-Friendly

Since potencies often do not exist in isolation, and are typically exposed to many stimulus conditions, it can be quite difficult to determine just how the particles that instantiate them will behave. Luckily, the effects of stimulus conditions get weaker with distance, and often can be shielded. Thus, while the gravitational contribution from Alpha Centauri has some effect on massive particles on earth, that effect is insignificant relative to the gravitational effect of the earth's mass. Similarly, because oppositely charged stimulus conditions have opposite effects on a charged particle, they can be used to shield one another. Scientists rely on these features to carefully construct experimental setups in which a single potency's characteristic behavior can be observed.

To illustrate this phenomenon, consider a representative physics experiment, which measures gravitational attraction at very small distances.[18] In such an experiment, the physicists place two masses very close to each other and measure the force between

careful formulation would only posit a necessary connection when all factors in the potency as well as its stimulus condition were accounted for. Such a formulation has not been forthcoming in the literature, so for the purposes of this chapter, I rely on the standard formulation. But I happily acknowledge there is work to be done on this front to capture the true nature of the essential power that, say, masses have to attract one another.

[17] Alexander Bird offers some arguments for thinking spatiotemporal relations are also potencies, see Bird (2007a, ch. 7), but I doubt such a view could be metaphysically complete, so I assume that spatiotemporal relations are not potencies. For arguments that spatiotemporal relations cannot be potencies, see Ellis (2010).

[18] These details are from an experiment performed at the University of Colorado by Long et al. (2003).

them by how much they deflect the springs to which they are attached. Because the force of gravity is so weak, especially when compared to the electromagnetic forces, the biggest challenge of the experiment is to screen off as many outside effects as possible. Thus, the experiments are performed in a deep basement, in the dark, at night, and only during breaks in the traffic outside. This careful screening-off procedure is evidence that the physicists aim to discover the characteristic behavior (manifestation) of a specific *kind* of property (disposition). Cartwright (1999) describes a similar process in the case of measuring charge:

> To say it is in [the electrons'] nature to experience a force . . . is to say at least that they would experience this force if only the right conditions occur for the power to exercise itself 'on its own', for instance, if they have very small masses so that gravitational effects are negligible.
>
> (Cartwright 1999, 82)

By repeated applications of this procedure in different areas of fundamental physics, each potency can be ever more effectively isolated and its characteristic behavior in various conditions discovered. Why think these properties are dispositional rather than categorical? Scientists need only perform a relatively small number of experiments on a single kind of particle before they feel confident that they have captured its true nature, or, in my terms, the essential dispositions of its potencies. As Cartwright (1999) argues,

> For example, we measure, successfully, we think, the charge or mass of an electron in a given experiment. Now we think we know the charge or mass of all electrons; we need not go on measuring hundreds of thousands. In so doing we are making what looks to be a kind of essentialist assumption: the charge or mass of a fundamental particle is not a variable quantity but is characteristic of the particle so long as it continues to be the kind of particle it is.
>
> (Cartwright 1999, 85)

I argued in section 2.1 that when scientists formulate their systematic theories, they use simplicity and strength as standards for success. In this section, I gave reasons to think that when scientists investigate the nature of the fundamental properties, they look for dispositional essences, or what it is that things *do* in different situations. Thus, just as the best system account is a science-friendly account of the laws of nature, potencies constitute a science-friendly ontology.

4. Potency-Best System Account of Basic Laws

In this section, I combine potencies with the best system account of basic laws. I use Lewis's best system account of laws as a template, replacing his perfectly natural categorical properties with sparse, dispositional properties (i.e. with potencies). The other crucial difference is that I systematize the potencies in many possible worlds, not just one. More specifically:

> **Potency-BSA:** The basic laws of nature at w are the axioms of the simplest, most informative, true systematization of all w-potency-distributions, where a w-potency-distribution is a possible distribution of only potencies appearing in w.[19]

For example, if a world, w_1, contains a possible distribution of the potency of mass, then the laws of w_1 must systematize all possible distributions of mass. Since the possible distributions of mass are determined by the potencies and not the laws, there is no threat of circularity. If another world, w_2 contains a possible distribution of the potencies of mass and charge, then the laws of w_2 must systematize all possible distributions of mass, all possible distributions of charge, and all possible distributions of both mass and charge. Thus, any systematization that fails to reference those potencies fails to be an eligible candidate for lawhood. In the same way that Lewis's perfectly natural, categorical-BSA rules out a trivial best system, so does the potency-BSA—in this case '$(\forall x)Px$,' where P is the potency had by all and only objects satisfying a given systematization. And, as I will show below, this account does not succumb to the three objections discussed above.

4.1. Why Systematize Properties in non-Actual Worlds?

Recall that every Humean version of the BSA systematizes the properties of the actual world. But, with the introduction of potencies, properties that are primitively modal, there is no additional cost to include other possible distributions in our systematization. As discussed above, the initial distribution of potencies determines the later distributions (by *production*, which I discuss below). Because the laws include systematizations of all the ways in which initial configurations of dispositional properties can evolve, it allows us to characterize the laws of nature without including any actual, but accidental generalizations, and without omitting any non-actual, but lawful regularities.

Why can't the Humean systematize the distribution of properties in non-actual worlds? First, the Humean would need a way of characterizing the other worlds. Granting that, the Humean would need to identify the right set of worlds to systematize for the laws. Choosing only those worlds at which the laws of nature hold would be obviously circular since the systematization is meant to ground the laws, not the other way around. On the other hand, the Humean cannot systematize all of the worlds that instantiate the perfectly natural properties found in the actual world, as I do with potencies, because it would include too many worlds. Since the categorical properties are not connected to the behaviors of the particles that instantiate them, they can appear in vastly more combinations than potencies. Therefore, the laws would have to systematize worlds that differed in radical ways from each other. There would be no non-trivial regularities between such disparate worlds, and thus, no BSA laws.

[19] David Albert (2000) persuasively argues that an additional, low-entropy restriction on possible initial distributions is necessary to recover the special science laws. But for the purposes of this chapter, I am concerned only with the basic laws of nature.

Therefore, the only reasonable option for the Humean is to systematize the distribution of properties in the actual world.

4.2. A Potency-BSA Matches our TOE

Let us return to the mismatch objection. Suppose, again, that our best scientists have arrived at a very simple, very informative final theory of everything (TOE) that correctly predicts as wide a range of empirical data as scientists can test. What are our reasons for thinking such a theory will match the potency-BSA?

Recall that potencies—primitive, sparse properties with unique dispositional essences—are necessarily connected to the behavior of the particles that instantiate them. So, almost any permutation of potencies will affect the trajectories of particles, unlike in the case of categorical properties, as we saw in section 2.2. This is where the ontology of potencies and the best system account of laws complement each other so well. Since the scientists' TOE systematizes the trajectories of particles, and since the trajectories of particles are *produced by* the potencies, we have good reason to think that a simple, informative TOE will appeal to those potencies.

By positing an ontology of potencies, we have ruled out the vast majority of ways in which a best system could fail to match our TOE. However, there is still no guarantee (again, nor *should* there be) that the trajectories of the particles will yield enough information for scientists to uniquely identify every potency. For instance, if there are only a few potencies instantiated in only a few different kinds of situations, scientists would not be able to fully capture their modal profiles, and thus, their theory of everything would fall short of the best system.

However, there is reason to think that a complex world like ours is not impoverished in this way. Nature, it seems, eventually gets around to displaying all different kinds of behavior. And, if nature is not forthcoming, scientists perform experiments specifically designed to test for potencies in stimulus conditions that rarely occur on their own. For instance, scientists are able to perform experiments at very high energies which arose naturally only just after the Big Bang. Thus, the defender of the potency-BSA need not worry—beyond the unavoidable skeptical worries—that science fails to capture the genuine laws of nature. Similarly, there is good reason to think that a best system account that systematizes only the actual world, and that referred to potencies rather than categorical properties, would match the potency-BSA as well—another way of saying that actual scientists systematize actual behavior that is determined by the potencies.

4.3. Impoverished Worlds and the Potency-BSA

Since the potency-BSA systematizes the distribution of potencies in all possible worlds that contain the same potencies, an impoverished world will receive the same systematization as a complex world. Consider, again, a world with a single massive particle, traveling inertially for all time. The laws of this world will systematize not just this world, but all worlds that contain mass. Therefore, it will be a law that all massive particles attract each other, and NOT that they always travel inertially. Furthermore, even without developing a theory of how counterfactuals depend upon the potencies and laws, it is easy to see that *if* that single particle *were* near another massive particle, it *would* experience attraction toward that particle. Therefore, the potency-BSA laws are intuitively correct in impoverished worlds, and they yield the right counterfactuals for those worlds.

Of course, scientists of such a world would be in a kind of skeptical scenario, and thus unlikley to *arrive at* the correct account of the laws. Analogously, if our world turns out to be impoverished, we would be in a similar, unfortunate situation. But, this is the correct result—the laws of nature are not guaranteed to be epistemically accessible. The potency-BSA, and not the traditional BSA, secures the intuitively correct result in impoverished worlds, whether or not inhabitants of those worlds know it.

4.4. Potencies do Metaphysical Work

There is a very deep and interesting question about just how it is that a potency produces its characteristic behavior. Many philosophers, such as Bird, avoid this metaphysical question by appealing to counterfactuals. But while counterfactuals can tell us *what* behavior results from a configuration of potencies, they cannot tell us *how* that behavior results. Nevertheless, Bird (2007a, 200) claims, "Mumford and I agree that the existence of regularities in nature, the truth of counterfactuals, and the possibility of explanation are explained by the potencies."

So, Bird claims that the potencies are explanatory, but he says very little to illuminate how this explanation is supposed to go. Stipulating a biconditional between potencies and counterfactuals does not tell us how it is that the potencies *explain* the behavior of particles—even if those counterfactuals can be used to derive regularities. Entailment falls short of metaphysical explanation. To see this, consider that Lewis's best system account of laws entails facts about how particles behave. Despite this, the laws do not (metaphysically) explain the behavior of particles. On the contrary, it is the distribution of properties that explains the categorical-BSA laws.

I think the most promising solution is to appeal to *production*—dynamic, metaphysical dependence. According to my view, the fundamental ground includes spacetime and an initial arrangement of particles and potencies. And the subsequent behavior of the particles (further potency instantiations as well as trajectories through spacetime) is dynamically, metaphysically dependent upon that base. Since the potency-BSA systematizes those trajectories, the laws of nature are not fundamental, and do not govern, but rather depend upon the behavior of the particles and potencies. To summarize what (metaphysically) explains what: on my view, the initial distribution of particles and their potencies dynamically ground the subsequent behaviors of particles and subsequent property instantiations. And, all of the possible initial distributions and evolutions determine the (metaphysically inert) laws.[20]

If the fundamental properties are potencies, they can do the metaphysical heavy lifting many have thought had to be done by the laws of nature. The intuition about metaphysical 'oomph' is that the behavior of particles in our universe is not primitive but, rather, is produced (or governed) in a systematic way. One option is to locate this power in *governing* laws of nature, which 'push and pull' the particles around. But, if the fundamental properties turn out to be dispositional, rather than categorical, then the potencies are a natural place to locate metaphysical power,[21] as they *produce* the behavior. If the potencies bear the metaphysical responsibility for the behavior of particles, then the laws of nature are no longer needed for this role. This makes a best system account, which eschews just such a role, perfectly suited to a fundamental ontology of dispositional properties.[22] Thus, we can reconcile the thought that 'oomph' is needed in the world while retaining the BSA and its tight connection to scientific practice.

5. Conclusion

In this chapter, I have argued that a best system account of laws and an ontology of fundamental dispositional properties are well-suited to each other. Physicists test for potencies, and formulate laws that systematize trajectories, while maximizing simplicity and strength. This makes an ontology of potencies and best system laws science-friendly. In addition, my potency-BSA can avoid three objections that plague the categorical-BSA. Because potencies are necessarily connected to the behavior of the particles that instantiate them, the potency-BSA avoids the mismatch objection.

[20] Much more could be said about such a relation. For instance, each arrangement of particles and their potencies is probably best explained in terms of the previous (or in the limit) arrangement of particles and their potencies, perhaps just in the past light cone of the arrangement in question.

[21] Indeed, Bird (2007a, 46) takes potencies and powers to be the same thing: "potencies just are their dispositional powers." Mumford (1998) and Bird (2007a) agree that governing laws are superfluous with an ontology of potencies.

[22] Markus Schrenk (2012) objects,

> if nature equips properties with their own (causal) essences then what would be the point of a Lewisean best system analysis? Most causal roles and, thus, causal laws would anyway already be fixed by the properties' essences and, so, a best system competition would at best deliver exactly those already given laws and roles. (Schrenk 2012, 8)

But, while laws of nature are, indeed, fixed by dispositional essences, they are distinct from them. The difficulties that beset attempts to state dispositional essences do not beset similar attempts to state the laws of nature. For instance, even if the potencies are restricted to include only mass, there is a great deal of controversy as to what the dispositions are. Are masses simply disposed to attract one another, with perhaps a meta-disposition for how those massive attractions add to or subtract from one another? Or are there separate dispositions for each particular possible mass-instantiation distribution? If, instead, the laws systematize the possible distributions of potencies throughout spacetime, there is the possibility of 'backsolving' to arrive at the potencies. And, it is likely that this is exactly what metaphysicians do when they discuss dispositions such as mass and charge. But, of course, the metaphysical direction of explanation need not point the same way as the epistemic one.

Because the potency-BSA systematizes all worlds with the relevant potencies, rather than just one, it avoids the impoverished worlds objection. Finally, I have argued that potencies can play the metaphysical role of production traditionally reserved for governing laws of nature. So it makes sense to think that the laws of nature are metaphysically inert, just as they are in a best system account. Thus, I hope to have shown that potencies and the best system account of laws complement each other nicely and make for a promising picture of the fundamental ontology and the laws of nature.

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