Philosophy and
Phenomenological Research

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The Essence of Dispositional Essentialism

DAVID YATES
King's College London

1. Introduction

Some natural properties have causal roles; call these 'causal properties'. Dispositional essentialists think that some causal properties have their causal roles *essentially*. For the purposes of this paper, I treat dispositional essentialism (hereafter 'DE') as a claim about the properties of (ideal, completed, fundamental) science.[1] If the basic ontology of completed science (hereafter 'Physics') includes charge, and attributes to it the causal role of repelling like charges, then repelling like charges is essential to charge. Dispositional essentialists often go further. The causal role R of charge isn't just essential to charge, R is the *individual essence* of charge—in addition to having R essentially, having R as opposed to some other causal role is what makes charge the property it is, rather than some other property.[2] By contrast, categoricalists hold that Physical properties have no essential (non-trivial) modal character. A canonical explanation of why such properties have their inessential causal roles appeals to laws of nature.[3] That charge has R is determined by a second-order relation of 'contingent necessitation'—such relations (so to speak) tell categorical properties what to

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[1] My arguments don't apply to versions of DE concerned with natural kinds, e.g., Ellis (2001).

[2] In other words, R *individuates* charge. In my usage 'DE' refers to this stronger position.

[3] See Armstrong (1983). Lewis's (1973) account is an exception, taking the causal roles of natural properties to supervene on their distribution throughout space-time. I treat Armstrong's account as the canonical form of categoricalism.

do. Laws of nature are contingent facts of the form N(F,G), where N confers modal character upon F and G.[4] Although it's *nomically* necessary that like charges repel, there are possible worlds where like charges attract. The laws of nature determine the causal roles of properties. Given DE, by contrast, no possible property P such that like Ps attract is the same property as charge. The natures of properties determine the laws of nature. Dispositional essentialists are therefore (typically) necessitarians about laws—any world with the same collection of Physical properties as ours is *ipso facto* a world with the same laws of Physics.[5]

The role of the concept of essence in dispositional essentialism has received little attention in the literature, and DE therefore stands in need of interpretation. The structure of this paper is as follows. I first set out desiderata on a theory of essence suitable for interpreting DE by considering the epistemological and metaphysical work proponents of DE expect it to do. I proceed to show how DE can be interpreted in a way that meets all these desiderata by the traditional modal account of essence (hereafter 'modalism'), according to which the essential properties of an entity are all and only those *sine qua non*. I then argue that modalism results in incorrect associations of basic physical properties with dispositions, and that as a result DE requires a primitive conception of essence. I develop an interpretation of DE based on Kit Fine's theory of essence, which has all the epistemological and metaphysical virtues of its modal counterpart, and significant metaphysical virtues its modal counterpart lacks. It's crucial to my arguments that the properties in the scope of DE are transworld entities. I follow Jonathan Schaffer in holding that the transworld identity of properties—whether these be understood as universals[6], tropes[7], or classes of possibilia[8]—is no more problematic than their trans-temporal identity.[9] I remain neutral as to whether dispositions are amenable to analysis (conditional or otherwise); likewise on the issue of whether dispositions are

[4] I will often speak loosely, in what follows, of laws governing categorical properties. Strictly speaking, it is N-relations that govern; a law of nature is the fact that N(F,G).

[5] Some, e.g. Hendry and Rowbottom (2009), argue that dispositional essentialism is consistent with slight variations in the laws of nature. These matters are beyond the scope of the present paper.

[6] Armstrong (1997).

[7] Campbell (1990).

[8] Lewis (1986).

[9] Schaffer (2005), pp. 13–14.

second-order functional properties, or can be ungrounded.[10] For now, I commit only to the following theses: (i) dispositions are genuine properties, (ii) the identity of dispositions is determined by their stimulus conditions and manifestations. I endorse (i) because I require transworld identity of the dispositions that define Physical properties. Given (ii), dispositions are fine-grained—the disposition to M when C is identical to the disposition to M′ when C′ only if $C = C'$ and $M = M'$. Fineness of grain is arguably entailed by functionalism about dispositions, but is consistent with other positions.[11]

2. Why Be a Dispositional Essentialist?

Arguments for DE focus on epistemological and metaphysical problems with categoricalism. Dispositional essentialists say categoricalism (i) renders properties epistemically inscrutable, and (ii) is of dubious metaphysical cogency. These are the problems that a well-motivated DE needs to solve, and they will therefore supply principled constraints on the suitability of theories of essence for interpreting DE. Categoricalists hold that Physical properties have no (non-trivial) essential modal character. If (as categoricalists typically do) we allow that properties are transworld entities, it follows that transworld identity of properties isn't determined by their causal roles.[12] In fact, categoricalists are often *quidditists*, and so deny that there's anything to the natures of basic properties other than primitive identity and difference.[13] On this view, transworld identity of properties isn't determined by anything at all, hence *a fortiori* isn't determined by causal role. I won't concern myself with quidditism here, and don't claim that categoricalism entails it. Assume for the time being an intuitive notion of causal role as applied to properties, according to which a property's causal role is its potential for contributing to causal relations. Any feature of a property that renders it *detectable* will be

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10 See Lewis (1997), Fara (2005) for conditional and non-conditional analyses, respectively, of disposition ascriptions. Mumford (1998) and Molnar (2003) deny that any such analyses are possible. Lewis and Fara give treatments consistent with the second-order functionalist approach to the metaphysics of dispositions endorsed by Prior, Pargetter and Jackson (1983), while Molnar and Mumford take some dispositions to be ungrounded, hence not second-order properties.

11 Mumford (1998, p. 198) and Molnar (2003, p. 195) endorse (ii); Martin (2007) holds that any given disposition has many different possible manifestations depending on its 'reciprocal disposition partners'. Mainstream opinion among dispositional essentialists, however, is that dispositions are fine-grained.

12 See Schaffer (2005) pp. 4–5; Bird (2007) pp. 70–71.

13 See for instance Armstrong (2004), p. 146.

part of its causal role.[14] Thus, (1) categoricalism makes the transworld identity of Physical properties independent of any of the features in virtue of which we are capable of detecting them; (2) we need governing laws to explain why categorical properties have causal roles.

2.1. Epistemology

Consider gravitational mass and charge. Categoricalism entails the following theses, which give rise to the sceptical worries that motivate DE:

(i) Permutation: There's a possible world *w*P that differs from actuality (*w*A) only in that at *w*P, mass plays the charge role, and charge plays the mass role.

(ii) Replacement: There's a possible world *w*R that differs from actuality only in that charge is replaced by an alien property 'schmarge' that plays the charge role.

(iii) Duplication: There's a possible world *w*D where two properties play the charge role.

David Lewis employs (i) and (ii) in his (2009) arguments for 'Ramseyan humility'.[15] Focus on (i). Physicists at *w*P agree that there is a property (the property they call 'charge', which is primitively identical to the property we call 'gravitational mass') that comes in positive and negative varieties, is such that opposite signs attract, etc. Let 'Physics(*w*)' abbreviate 'the Physics true at world *w*'; we can write Physics(*w*A) as $\mathrm{T}[\mathrm{t}_1 [\ldots] \mathrm{t}_\mathrm{n}, \mathrm{o}_1 [\ldots] \mathrm{o}_\mathrm{n}]$ where the t_i are the theoretical terms of T and the o_i are all the other terms, which have their meanings fixed independently of T. (Assume our o-language has a rich enough stock of o-terms to express all possible observations.) By hypothesis, all that differs between *w*A and *w*P are the referents of some of the t_i (in this case 'charge' and 'mass') so we can write Physics(*w*P) as $\mathrm{T}[\mathrm{t'}_1 [\ldots] \mathrm{t'}_\mathrm{n}, \mathrm{o}_1 [\ldots] \mathrm{o}_\mathrm{n}]$. To derive the Ramsey-sentence of a theory we replace the t-terms with bound variables, so the Ramsey-sentence of both Physics(*w*A) *and* Physics(*w*P) is R(T): $\exists! x_1 [\ldots] x_\mathrm{n} \mathrm{T}[x_1 [\ldots] x_\mathrm{n}, \mathrm{o}_1 [\ldots] \mathrm{o}_\mathrm{n}]$. Assuming (with Lewis) that each t-term has a

[14] If we are capable of detecting instances of a property, then that property must contribute to causal relations between its instances and whatever sensory or scientific equipment we use to detect it. I finesse the notion of a property's causal role in due course.

[15] Lewis (2009).

unique referent at each world, R(T) is true at both *w*A and *w*P. Since a theory and its Ramsey-sentence have the same observational consequences, it follows that R(T) has the same observational consequences as both Physics(*w*A) and Physics(*w*P), so the observational consequences of Physics(*w*A) and Physics(*w*P) can't differ. Hence Lewis's sceptical conclusion: we can't know whether we are in *w*A or *w*P.[16] By parity of reasoning, we can't know whether we are at *w*A or *w*R, since the Ramsey-sentence of Physics(*w*R) is also R(T). Since the property that occupies the charge role is different at *w*A, *w*P and *w*R, it follows that we can't know which property occupies the charge role. Whence an anti-sceptical modus tollens: (1) If categoricalism is true, we can't know which property occupies the charge role; (2) we *can* know which property occupies the charge role; so categoricalism is false.

Alexander Bird and Sydney Shoemaker offer sceptical arguments based on duplication.[17] Shoemaker worries that "[...] if two properties can have exactly the same potential for contributing to causal powers, then it's impossible for us even to know (or have any reason for believing) that two things resemble one another by sharing a single property".[18] If it's possible for two properties to have the same causal role, then it's possible for there to be two things with different properties which have exactly the same effects on us and on any possible detector. Such possibilities, Shoemaker argues, preclude our knowing that two things share a property. To complete the anti-categoricalist argument, add in the premise that we *can* know when things share a property, and conclude that categoricalism is false. Similarly, Bird worries that if there were two properties playing (for instance) the charge role, then on certain reasonable assumptions about reference-fixing, 'charge' fails to refer. This is clearest if we take theoretical terms to be *defined* by the Ramsey-sentences of the theories they feature in, so that 'charge' means 'the unique actual occupant of the charge role'. If there's more than one actual occupant of the charge role, then 'charge' doesn't refer. But if categoricalism is true, we can't know that any causal role is uniquely occupied. It's because we can't know, for instance, that the charge role is uniquely occupied, that we can't know (i) that two things share a property when charged, (ii) whether 'charge' refers. A second *modus tollens* suggests itself: (1) if categoricalism is

16 Lewis's argument isn't the only route to the conclusion that Physics isn't the whole truth about the physical world. For more on the view that physical entities have intrinsic natures not captured by Physics, see Russell (1927); Blackburn (1992).

17 Shoemaker (1980) pp. 257–260; Bird (2007) pp. 76–79.

18 Shoemaker (1980) p. 258.

true, we can't know whether theoretical terms refer; (2): we *can* know that theoretical terms refer; so categoricalism is false.

2.2. Metaphysics

Categoricalism, if true, should apply not only to first-order properties, but also the second-order properties that govern them. Bird argues that the role categoricalists afford to laws of nature is at odds with categoricalism.[19] Here's a simplified version of Bird's argument. If a law of nature N(F,G) *entails* extensional inclusion ($\forall x[F(x) \rightarrow G(x)]$) then N has modal character, viz., conferring extensional inclusion on the ordered pair (F,G). But according to categoricalism, no properties have any *essential* non-trivial modal character, so it's possible that $N(F,G) \wedge \neg \forall x[F(x) \rightarrow G(x)]$. Why then should N confer extensional inclusion on (F,G) at *any* world? We seem to require a further law N' such that N'[N(F,G)]. If N' = N, then the account is circular, since the question at issue is how, given that it has no essential modal character, N manages to confer extensional inclusion. If N ≠ N', then the account is regressive, for the question now arises as to why N' should confer upon N the power to confer extensional inclusion upon (F,G). It seems categoricalists must allow N to have essential modal character, but then why not say instead that F and G have their causal roles essentially, thereby obviating the need for N in the first place? Categoricalism only makes sense if the N-relations have their governing roles essentially. But if we're prepared to abandon categoricalism about N, why not abandon it altogether? DE, say its proponents, gives us the laws of nature for free, by telling about first-order properties the story that categoricalists must tell about second-order laws.

2.3. Desiderata

I needn't comment further on the arguments outlined above.[20] The permutation, replacement and duplication arguments aim to show that categoricalism is false. Assume these arguments are sound. Premise (1) of each argument states that categoricalism rules out certain kinds of knowledge of Physical properties. Since premise (2) of each argument states that we *can* have the kind of knowledge categoricalism rules out, and DE is the negation of categoricalism, it follows that DE must be consistent with our having such knowledge. Since it's the fact that

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19 Bird (2005; 2007 pp. 91–97); see also Mumford (2004).

20 For discussion of epistemological arguments against quidditism, see Hawthorne (2001), Schaffer (2005); on Lewis's arguments for humility see Whittle (2006), Locke (2009).

categoricalism entails the existence of possible worlds wP, wR and wD that licenses scepticism, DE must be so defined as to entail that there are no such possible worlds. If DE is also to be supported by problems with the governing laws of nature categoricalists require, then it should in addition be so formulated as to show that we get the laws of nature for free.

3. Dispositional Essentialism I: Modal Essence

In this section I show how DE can be formulated using a traditional modal conception of essence, and argue that the resulting theory meets the desiderata of (2.3). According to modalism, the essential properties of a particular are all and only those *sine qua non*. I will use '$\Box$' to denote metaphysical necessity, and interpret such necessity in terms of truth at all possible worlds. Thus in my usage '$\Box$' isn't semantically neutral, and should be read as an unrestricted quantifier ranging over possible worlds. Correspondingly, '$\Box\forall x$' should be read as an unrestricted quantifier ranging over all possible xs ('for any x, at any possible world').

3.1. Modalism about Essence

I begin with a standard formulation of modalism:

$$\text{MOD}: \forall x \forall \text{P}[\text{P is essential to } x \leftrightarrow \Box\forall y\{y=x \rightarrow \text{P}(y)\}]$$

(MOD) reads: P is essential to x iff if any y, at any possible world, is identical to x, then P(y). Three points are in order. First, it doesn't follow from (MOD) that x has P at every possible world—what follows is that x has P wherever $\exists y.y=x$. Second, since the quantifier that binds x occurs outside the scope of the modal operator, the right hand side of the biconditional expresses a condition on x's transworld identity. Third, (MOD) accords well with certain pre-theoretic intuitions about the meaning of 'essence'. For instance, (MOD) entails that if having my actual biological parents is essential to me, then however the world had turned out, had it not contained anything with my parents, it wouldn't have contained anything identical to me. We can adapt (MOD) to give an analysis of *individual essence*, as follows:

$$\text{MOD}^+: \forall x \forall \text{P}[\text{P is an individual essence of } x \leftrightarrow \Box\forall y\{y=x \leftrightarrow \text{P}(y)\}]$$

The biconditional on the right hand side of (MOD^+) gives necessary *and* sufficient conditions on x's transworld identity. Informally, my individual essence is a (possibly improper) subset of my essential properties such that if anything, at any world, has all the properties in the set, then it's identical to me. In addition to my having P essentially, everything that isn't identical to me essentially *lacks* P. Two entities might share *some* of their essential properties, but not their individual essences, nor, *ipso facto*, *all* their essential properties. Individual essences are more than extensionally adequate identity criteria—they *determine* the facts of numerical identity and difference for the entities in a given class.[21]

Readers familiar with Fine's arguments against modalism may wonder why I consider modal essence as a way of formulating DE at all.[22] Fine argues that Socrates' membership in the singleton set {Socrates} is a counterexample to modalism. Socrates belongs to {Socrates} at any possible world where he exists, and necessarily nothing other than Socrates belongs to {Socrates}, so membership in the singleton set ought to be essential to, and an individual essence of, Socrates. Intuitively, however, membership in {Socrates} is no part of what determines Socrates' identity. By contrast, having Socrates as its sole member *does* determine the identity of {Socrates}, but modalism fails to capture this asymmetry.[23] A promising strategy is suggested by Michael Della Rocca.[24] Read '$\lambda x.p$' as 'the property of being an x such that p', and '$(\lambda x.p)a$' as 'a has the property of being an x such that p'. Following Della Rocca, let a *trivial* necessary property be either (i) a necessary property of every entity, or (ii) a logical consequence of a property that's trivially necessary according to (i). For instance, everything is necessarily self-identical, so $(\lambda x.x=x)a$ is trivial in sense (i). But from $(\lambda x.x=x)a$ it follows logically that $(\lambda x.x=a)a$, so a's being necessarily identical to a, while not universally necessary, is trivial in sense (ii). The property $\lambda x.x \in \{x\}$ is trivial in sense (i): necessarily, everything belongs to its own singleton. But it follows logically from $(\lambda x.x \in \{x\})a$ that $(\lambda x.x \in \{a\})a$. Hence $\lambda x.x \in \{a\}$ is trivial in sense (ii). Trivial necessary properties are either properties an entity has solely in virtue of *being an entity*, or which follow logically from its having such properties. Della Rocca suggests that they are therefore unsuitable as essential properties, since these should be properties an entity has in virtue of *being the specific entity it is*. Where $\mathrm{T}[\mathrm{P}(x)]=\mathrm{P}$ is a trivial necessary property of x:

$$\text{MOD}{*}\text{: } \forall x \forall \mathrm{P}[\mathrm{P} \text{ is essential to } x \leftrightarrow \{\Box \forall y[y=x \rightarrow P(y)] \wedge \neg \mathrm{T}[\mathrm{P}(x)]\}]$$

21 My understanding of 'individual essence' is thus very close to Mackie (2006).

22 Fine (1994).

23 Fine gives other examples, including Socrates' necessary non-identity with the Eiffel Tower. The arguments I suggest below apply *mutatis mutandis* to these other examples.

24 Although not as a reply to Fine. See Della Rocca (1996), pp. 2–3.

As required, (MOD*) implies that $\lambda x.x \in \{\text{Socrates}\}$ isn't essential to Socrates. By contrast, (MOD*) entails that $\lambda x.\text{Socrates} \in \{x\}$ *is* essential to {Socrates}, for $\lambda x.\text{Socrates} \in \{x\}$ isn't a universally necessary property, nor is $(\lambda x.\text{Socrates} \in \{x\})\{\text{Socrates}\}$ a logical consequence of a universally necessary property of {Socrates}. The mere fact that {Socrates} is self-identical, for instance, doesn't even entail that it's a set, let alone that it contains Socrates. If (MOD*) is defensible, then, it entails the asymmetry that Fine requires. In (4), I offer my own argument against modalism, which appeals to necessary properties that are neither essential nor trivial, and so refutes (MOD*), whatever its merits as a means of replying to Fine.

3.2. Modalism Applied to DE

DE is the thesis that properties are individuated by their causal roles, but it isn't obvious how to formulate this modally. What is it for a property to have a causal role? Dispositional essentialists take the causal roles of properties to consist in determining, or contributing to, the dispositions of their bearers; for this reason, they often express their view by saying that Physical properties have *dispositional essences*.[25] Two options remain: either (i) identify Physical properties with dispositions, or (ii) take the identity of Physical properties to be defined in terms of dispositions they bestow upon their bearers.[26] I think that (i) is untenable on a fine-grained conception of dispositions. The reason is that properties such as charge are associated with *multi-track* dispositions. According to Coulomb's law, the force that a particle x with charge q_i exerts on a particle of charge q_j at distance R_{ij} from x is:

$$F_{ij} = \frac{k_e q_i q_j}{R_{ij}^2}$$

where k_e is Coulomb's constant.[27] Given (i), each specific quantity of charge q_i is identical to an infinite conjunction of dispositions whose stimuli are charges q_j at distances R_{ij}, and whose manifestations are forces F_{ij}. As Bird argues, it's difficult to regard such conjunctions as fundamental properties, since the conjuncts are surely *more* fundamental.[28] Option (i) places *a priori* constraints on the kind of properties

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25 In (5.3) I argue that this notion of causal role is too tightly circumscribed, but grant it until then.

26 Bird (2007) and Molnar (2003) endorse option (i); Shoemaker (1980) favours option (ii).

27 $k_e = 1/4\pi\epsilon_0$ where ϵ_0 is the permittivity of free space. $k_e = 8.99\ \text{Nm}^2/\text{C}^2$.

28 Bird (2007) pp. 20–24.

that could be fundamental, but this is surely a matter for scientists to decide. In addition, there's no obvious way for Bird to explain why certain fundamental dispositions are unified into conjunctive properties such as the q_i. Why don't we find charged particles that exert force F_e on particles with charge e, but which fail to exert $-F_e$ on particles with charge $-e$, if these dispositions are distinct fundamental properties? For these reasons, I treat DE (assuming for now that causal roles are to be understood dispositionally) as the claim that Physical properties essentially *bestow* certain dispositions, which leaves room for them to be ontologically basic yet dispositionally complex. George Molnar maintains that Physical properties are ungrounded or 'pure' powers, which have a kind of brute physical intentionality, in that they are *directed towards* their manifestations.[29] It may appear that Molnar's position is ruled out by the claim that Physical properties bestow dispositions, but this isn't the case. Suppose we take the disposition of electrons to repel other electrons to be a second-order functional property, realized by their charge.[30] This is consistent with the claim that charge itself is an ungrounded *power*, provided we don't identify such powers with dispositions.[31] Let F range over causal properties, ϕ over sets of dispositions. I define 'bestowal' as follows:

B: $\forall F \forall \phi [F \text{ bestows } \phi \leftrightarrow \forall x \{F(x) \mathrel{\Box\!\!\rightarrow} \phi(x)\}]$ [32]

Following Robert Nozick, I take subjunctives to be weakly centred on actuality, so that $p \mathrel{\Box\!\!\rightarrow} q$ is true iff q is true at every world in the p-neighbourhood of actuality, which may include, but isn't thereby limited to, actuality itself.[33] According to (B), F bestows ϕ iff for any x, all worlds in our $F(x)$-neighbourhood are $\phi(x)$ worlds. (B) is neutral between categoricalism and DE, since neither worlds with different

29 Molnar (2003).

30 For instance, the property of having some property in virtue of which its bearer repels electrons. See Prior, Pargetter and Jackson (1982) for more on functionalist approaches to dispositions.

31 Molnar calls this 'truncated functionalism', and rejects it on the grounds that it precludes there being anything dispositional about both the ungrounded powers and the functional dispositions they bestow. I disagree—being essentially such as to realize functional dispositions is one way of being dispositional; being such a disposition is another. See Molnar (2003) , pp.140–141.

32 I use the subjunctive here because a material conditional would entail that uninstantiated properties trivially bestow every disposition.

33 Nozick (1981), pp. 680–681. A world w' is in the p-neighbourhood of a world w iff (i) p is true at w', (ii) there are no worlds w^p and w^{p-} such that (a) p is true at w^p and false at w^{p-}, (b) w^{p-} is closer than w' to w, and (c) w^p is at least as close as w^{p-} to w.

governing laws of nature, nor worlds with different natural properties, will be in the relevant neighbourhood. (MOD^+) equates the individual essence of any x with a property P of x such that for any y, at any possible world, y has P iff $y = x$. Since properties are related to dispositions by bestowal rather than identity, we must equate the dispositional essence of a property F with a set ϕ of dispositions such that for any property P, at any possible world, P bestows ϕ iff P = F. Adapting (MOD) and (MOD^+) for second-order quantification, and combining with (B), we can derive modal definitions of dispositional essence and individual essence:

$$\forall F \forall \phi [\phi \text{ is essential to } F \leftrightarrow \Box \forall P\{P = F \rightarrow \forall x[P(x) \mathrel{\Box\!\!\rightarrow} \phi(x)]\}]$$

$$\forall F \forall \phi [\phi \text{ is an individual essence of } F \leftrightarrow \Box \forall P\{P = F \leftrightarrow \forall x[P(x) \mathrel{\Box\!\!\rightarrow} \phi(x)]\}]$$

3.3. Modal DE, Scepticism and the Laws of Nature

We may now see how modally interpreted DE meets the desiderata of (2.3). Let q = charge, with individual essence ϕ_q. Then we can deduce:

$$\text{CH: } \Box \forall P[\forall x\{P(x) \mathrel{\Box\!\!\rightarrow} \phi_q(x)\} \leftrightarrow P = q]$$

To get from actuality to *w*R we imagine an alien property occupying the charge role; to get to *w*D we imagine two properties occupying the charge role. According to (B), a property P at a world w has the causal role of charge iff $\forall x[P(x) \mathrel{\Box\!\!\rightarrow} \phi_q(x)]$. But reading (CH) from left-to-right, any property, at any world, that meets this condition, *just is* charge. Individual essences can't be common to numerically distinct entities. In both cases, then, we misdescribe what we imagine. At *w*R our putatively alien property is charge, so not alien; at *w*D we haven't imagined two properties but the same property twice. Permutation is ruled out twice over. To get from actuality to *w*P we imagine that mass and charge exchange causal roles. Reading (CH) from right-to-left, had we imagined a property identical to charge at *w*P, we would have imagined a property with the charge role; ditto mass. Reading from left-to-right, had we imagined a property that occupies the charge role at *w*P, we would have imagined charge; ditto mass. Modal DE therefore rules out all the epistemically troublesome possibilities.

Let's turn now to the laws of nature.[34] For reasons that will become clear, we must focus on specific quantities of charge. According to

[34] My treatment up to (L) follows that found in Bird (2007), ch.3.

Coulomb's law, each quantity q_i of charge is associated with an infinite set of dispositions, whose stimuli are charges q_j at distances R_{ij} from q_i, and whose manifestations are the forces F_{ij} which the q_i exert on the q_j. Associated with each specific quantity of charge q_i, then, there will be a distinct infinite set ϕ_i of dispositions. From (CH), suitably modified, it follows that no possible instances of q_i lack ϕ_i:

U: $\Box\forall x[q_i(x) \ \rightarrow \ \phi_i(x)]$

To see this, pick an arbitrary world w and an arbitrary individual a such that $q_i(a)$ at w. From (CH) we can conclude $\phi_i(a)$. Since a was arbitrary, $\forall x[q_i(x) \rightarrow \phi_i(x)]$ at w. Since w was arbitrary, $\Box\forall x[q_i(x) \rightarrow \phi_i(x)]$. Bird assumes a conditional analysis of dispositions:

CA: $\Box\forall x[\phi_i(x) \leftrightarrow \{\mathrm{S}_j(x) \ \Box\!\!\rightarrow \mathrm{M}_{ij}(x)\}]$[35]

where $\mathrm{S}_j(x) =_{\mathrm{df}}$ there's a particle y of charge q_j at distance R_j from x, and $\mathrm{M}_{ij}(x) =_{\mathrm{df}}$ x exerts a force of F_{ij} on y. For fixed values of i, the right-hand-side of (CA) is an infinite conjunction of subjunctives, one conjunct for each value of j. From (U) and (CA) it follows that $\Box\forall x[q_i(x) \rightarrow \{\mathrm{S}_j(x) \ \Box\!\!\rightarrow \mathrm{M}_{ij}(x)\}]$. Let a be an arbitrary individual at an arbitrary world w, such that $q_i(a)$. Suppose further that $\mathrm{S}_j(a)$. It follows that $\mathrm{M}_{ij}(a)$. Since a, w were arbitrary:

L: $\Box\forall x[\{q_i(x) \wedge \mathrm{S}_j(x)\} \ \rightarrow \ \mathrm{M}_{ij}(x)]$

We have derived a set of universal generalizations (L) from a statement of the essential nature of F, and a conditional analysis of dispositions. DE enables us to think of the laws of nature as those universal generalizations that are derivable in this way. But what exactly have we derived? (L) represents an infinite conjunction of universally quantified conditionals. Consider an electron of charge $-e = -1.60 \times 10^{-19}$C, and a proton of charge $e = +1.60 \times 10^{-19}$C. Any particular conjunct of (L) will have the particles at a fixed distance—say 1 nm (1×10^{-9}m). From Coulomb's Law, the force in Newtons (N) the electron exerts on the proton is:

$$F = [\{(8.99 \times 10^9) \times (-1.60 \times 10^{-19}) \times (+1.60 \times 10^{-19})\}/ (1 \times 10^{-14})^2]N = -2.30 \times 10^{-10}N$$

Substituting these specific values in (L), we get:

35 Bird (2004) , (2007), ch.3.

L′: $\Box\forall x[\{x$ has charge $-e \wedge$ there's a particle y with charge e 1 nm from $x\} \rightarrow x$ exerts a force of -2.30×10^{-10}N on $y]$

The idea behind the derivation is as follows. Charge $-e$ essentially bestows upon any x the disposition to exert a force of -2.30×10^{-10}N on a particle y of charge e 1 nm away from x. From (CH) and (CA) we can deduce the determinate law (L′). If we plug in *all* the dispositions that charge $-e$ bestows, we can deduce an infinite conjunction of such determinate laws, which is equivalent to Coulomb's law for charge $-e$:

$$F_j = -\frac{k_e e q_j}{R_j^2}$$

Repeat for all other quantities of charge, and we will have derived (L), which is equivalent to Coulomb's law. The proposed derivation aims to show that we don't need to posit second-order universals to explain why Physical properties have their causal roles. Physical laws are logical consequences of statements of the dispositional essences of Physical properties, and so are an ontological free lunch. As Bird admits, finks and antidotes provide counterexamples to (CA): disposition ascriptions entail only hedged conditionals of the form $[S_j(x) \wedge$ finks and antidotes are absent$] \mathrel{\Box\!\!\rightarrow} M_{ij}(x)$, and we can derive only similarly hedged laws from them. Bird sees this as an advantage, because it shows why some laws—those deriving from dispositions that are susceptible to finks and antidotes—are *ceteris paribus*. Conversely, if some fundamental dispositions aren't susceptible to finks or antidotes, then they will ground strict laws. Modal DE meets our desiderata by (a) rendering sceptical scenarios impossible, and (b) enabling a derivation of laws from dispositional essences, thereby showing that the former are grounded in the latter. I now argue, however, that dispositional essentialism requires a primitive concept of essence.

4. Necessary Connections and Stray Essences

My argument against modalism is based on necessary connections between properties in physics. Like Fine's, my argument depends upon finding necessary properties that aren't essential, with the key difference that the properties to which I appeal can't be ruled out as essences on grounds of triviality. The argument has the following structure: (i) it's nomically impossible for charged particles to be less massive than the electron, from which, given DE, it follows that (ii) it's metaphysically necessary that charged particles have at least the electronic mass; (iii) modalism, combined with (ii), entails that certain dispositions essential to mass are wrongly counted essential to charge, from which we may conclude that (iv) modalism is false. In (4.1) I argue for (i)–(iii); in (4.2) I argue for (iv). It will be noted that since my argument relies on DE to undermine modalism, it can't rest on *modally interpreted* DE. This is unproblematic, because I rely only on the left-to-right parts of the definitions of modal essence given at the end of (3.2), which capture the relatively uncontroversial claim that if a property bestows a certain set of dispositions essentially, then it bestows those dispositions wherever it exists. This is an instance of the general claim that all essential properties are necessary. My argument against modalism, like Fine's, targets the claim that all necessary properties are essential.

4.1. Mass, Charge and the Problem of Stray Essences

There's currently no consensus among physicists as to whether massless charged particles could exist in nature. I will draw attention to two reasons to suspect a theoretical lower bound on the mass of charged particles. In quantum electrodynamics (QED), due to the Heisenberg energy-time uncertainty principle, the vacuum contains a sea of virtual particles which form in pairs then quickly annihilate each other. The uncertainty principle is a consequence of Schrödinger's equation, and states that the uncertainty ΔE in the energy state of a system is related to the time Δt it spends in that state as follows:

$$\Delta E \Delta t \approx \hbar$$

where $\hbar$ is the reduced Planck constant. By Einstein's energy-mass equation, the energy of an electron-positron pair is $2m_e c^2$, where m_e is the electronic mass and c the speed of light. This means that virtual electron-positron pairs can be created from quantum fluctuations in the vacuum energy, provided they pay back the energy they borrow within an interval:

$$\Delta t \lesssim \frac{\hbar}{2m_e c^2}$$

In the presence of an external electric field, virtual *charged* particles such as electron-positron pairs behave as short-lived electric dipoles—effectively, the external field induces a small opposite electric field in the vacuum. The overall field strength in the region is reduced, 'screening off' some of the charge producing the external field. This is known as *vacuum polarization*. In 1947, studying the emission spectrum of the Hydrogen atom, Willis Lamb and R. C. Retherford measured a difference between two energy levels predicted to be degenerate (of equivalent energy). This discrepancy—the 'Lamb shift'—is explained in QED as an effect of vacuum polarization. The first argument for a lower bound on the mass of charged particles to which I want to draw attention is due to Leslie Foldy, and proceeds as follows.[36] We can predict the Lamb shift with high accuracy from QED. The contribution of a charged particle to vacuum polarization is proportional to the square of its charge and inversely proportional to the square of its mass. Due to their relatively large masses, all known charged particles other than the electron and positron make a relatively small contribution. If particles of unit charge less massive than the electron were nomically possible, then their virtual particle-antiparticle pairs would make a large contribution to vacuum polarization, thereby spoiling the agreement between theory and experiment on the magnitude of the Lamb shift. Current agreement between theory and experiment predicts that all possible charged particles other than the electron and positron must make a comparatively small contribution to the Lamb shift, meaning they must be significantly more massive than the electron.[37] The second argument, due to Vladimir Gribov, also appeals to vacuum polarization, but is more technical.[38] In outline, Gribov argues that *massless* charged particles would have their charges completely screened off during creation, resulting in the creation of neutral particles instead. The explanation of this screening is once more the interaction of such particles with charged virtual particles in the vacuum. We can see the relationship between the two arguments as follows: Foldy offers an empirical argument that there can't be charged particles less massive than the electron, while Gribov offers a theoretical argument that charged particles can't be massless. The latter argues for a theoretical lower bound on the mass of charged particles, the former provides empirical evidence as to the value of that bound. Hereafter I assume for ease of exposition that vacuum polarization effects make it nomically impossible for there to be charged particles less massive than the electron.[39]

There's a quick and tempting route from (i) to (ii)—dispositional essentialists think the laws of nature follow from the natures of properties, and so are true wherever those properties exist. The vacuum polarization effects in virtue of which the electron is the least massive charged particle are consequences of Coulomb's law, which is true

[36] Foldy (1954).

[37] This argument presupposes that if a certain kind of charged particle is nomically possible, then even if we never see actual instances of that kind, it exists as short-lived virtual particle-antiparticle pairs in the vacuum. The accuracy with which we can predict the Lamb shift implies that charged particles less massive than the electron don't exist as such pairs, and therefore—whatever the reason—aren't nomically possible.

[38] Gribov (1982).

[39] Even if this isn't so, the arguments to follow go through *mutatis mutandis* provided *massless* charge particles are nomically impossible. I run it in terms of the electronic mass for clarity.

wherever charge exists, so it's metaphysically necessary that charged particles have at least the electronic mass. The quick route, however, is too quick. The arguments sketched above depend not only on Coulomb's law, but also on the Heisenberg uncertainty principle, which is a consequence of Schrödinger's equation. My argument shows only that charged particles have at least the electronic mass wherever charge exists *and Schrödinger's equation holds*. But if it's possible for charge to exist at worlds where Schrödinger's equation *doesn't* hold, then the vacuum polarization effects I employ to argue for a lower bound on the masses of charged particles won't occur wherever charge exists, and (ii) is false. And it seems that this *is* possible, since Schrödinger's equation is a general law of motion not tied to the nature of any particular force-generating property.[40] In order to get from (i) to (ii), I need to show that the existence of charge is sufficient for the truth of Schrödinger's equation.[41] Here is the time-dependent Schrödinger equation for a single particle moving in a radial potential V:

$$i\hbar\frac{\partial\Psi(r,t)}{\partial t} = \widehat{\mathrm{H}}\Psi(r,t)\ [\text{where } \widehat{\mathrm{H}} = -\frac{\hbar^2}{2m}\nabla^2 + V(r)]$$

Ψ is the particle's wavefunction, interpreted physically as encoding a probability distribution. The term on the left hand side represents the total energy of the particle, and the two terms of the Hamiltonian operator $\hat{\mathrm{H}}$ represent its kinetic and potential energies, in turn.[42] To derive $\hat{\mathrm{H}}$ for a particular case we need to specify V. For instance, for an electron orbiting a positively charged nucleus of atomic number Z, we substitute the Coulomb potential for $V(r)$ to get:[43]

$$i\hbar\frac{\partial\Psi(r,t)}{\partial t} = \left(-\frac{\hbar^2}{2m}\nabla^2 - \frac{k_e Z e^2}{r}\right)\Psi(r,t)$$

Once $\hat{\mathrm{H}}$ and appropriate boundary conditions are specified, we can solve for Ψ and calculate the probability distribution over the particle's possible states (position, momentum, etc.). Problematically, the same is true for all other potentials—Schrödinger's equation is a general law of motion, and isn't specific to any particular potential. How then could

40 I owe this objection to an anonymous referee.

41 I neither require nor endorse the converse claim.

42 $\nabla^2\Psi = (\partial^2/\partial x^2 + \partial^2/\partial y^2 + \partial^2/\partial z^2)\Psi$. The mathematical details aren't important here.

43 The Coulomb potential V between two point charges q_i and q_j is given by $V = k_e q_i q_j / R_{ij}$. The Schrödinger equation appeals to potentials rather than forces but the two are interchangeable.

the existence of charge suffice for its truth? Since Schrödinger's equation is a quantum mechanical analogue of Newton's second law of motion, a corresponding problem arises in the classical case. Suppose for argument that Newtonian mechanics is true. Newton's 2nd law (N2L) states that the force *F* on a particle equals the rate of change of its momentum:

$$F = m\frac{dv}{dt}$$

Thus far I have taken charge to be individuated by dispositions *to exert forces* as specified by Coulomb's law. If charge essentially bestows dispositions to exert forces but can exist at worlds where N2L doesn't hold, then there are worlds at which forces don't produce the accelerations N2L predicts. I now argue that this is incoherent, and that the existence of charge at a world is sufficient for the truth of N2L there. Either Newtonian forces are Physical properties, or they aren't.[44] If they are Physical, then forces are within the scope of DE. But in that case force has a dispositional essence, which essence is at least partially described by N2L.[45] Charge essentially bestows the disposition to exert the forces specified by Coulomb's law, and the exertion of a force is essentially such as to bring about the accelerations specified by N2L. The essence of charge, on this view, involves bestowing upon its bearers dispositions to acquire *further* properties—forces of mutual attraction or repulsion—whose essences are to produce certain accelerations in bodies of a certain mass. It follows that charge can't exist at worlds where Newton's law doesn't hold, because charge is individuated by the forces its bearers exert on each other, and forces by the accelerations they produce. If forces are Physical properties, then the existence of charge is sufficient for N2L. What should we say if forces aren't Physical properties? An obvious answer is that talk of the force acting on a body is shorthand for the distribution and Physical properties of other bodies capable of influencing its motion. N2L relates the acceleration of a body not to the force acting upon it, but to the distribution and properties of other bodies; Coulomb's law relates charge not to force, but to mass and acceleration. We can combine Coulomb's law and Newton's 2nd law to give an equation relating the accelerations of pairs of charged particles to their charges and masses:

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44 I won't speculate as to what kind of properties forces might be. See Massin (2009) for extended discussion.

45 It may not be fully so described, because in a system where multiple forces act on a body, N2L applies to the *resultant* force, but not the *component* forces. Nonetheless, the existence of force at a world will be sufficient for the truth of N2L there. I ignore this complication in what follows; see Massin (2009).

$$m_i \frac{dv_i}{dt} = m_j \frac{dv_j}{dt} = \frac{k_e q_i q_j}{R_{ij}^2}$$

A specific quantity q_i of charge, on the current theory, bestows the infinite set of dispositions to produce accelerations $k_e q_i q_j / m_j R_{ij}^2$ in particles of charge q_j, mass m_j at separation R_{ij}. Elimination of forces requires changing our conception of the dispositions that individuate q_i: now these dispositions have not only charges q_j and separations R_{ij}, but also masses m_j, as their stimulus conditions, and accelerations rather than forces as their manifestations. But in that case it's the *conjunction* of Coulomb's law and N2L that describes the dispositional essence of charge, so the existence of charge is once again sufficient for N2L. The same argument applies *mutatis mutandis* to Schrödinger's equation. Rather than taking charge to be individuated by dispositions to exert forces, we can think of its essence in terms of dispositions *to generate potentials*. As before, if potentials are Physical properties, then given DE they have dispositional essences described (at least in part) by Schrödinger's equation, in which case if it's essential to charge that it generates the Coulomb potential, the existence of charge is sufficient for the truth of Schrödinger's equation. If, on the other hand, potentials aren't Physical properties, then talk of a body moving in a potential is shorthand for the distribution and Physical properties of other bodies capable of influencing its motion. But then the disposition to generate a Coulomb potential is just the disposition to alter the wavefunctions of particles in the vicinity, in the manner specified by the conjunction of Schrödinger's equation with the Hamiltonian for the Coulomb potential. Either way, the existence of charge is sufficient for Schrödinger's equation.

At any possible world, every charged particle x will possess the disposition ϕ_m to exert a force $F \geq GM_eM_y/R_y^2$ on any massive particle y, where M_e is the electronic mass, M_y the mass of y, R_y the distance between x and y, and G the gravitational constant. But bestowing ϕ_m isn't part of what makes charge the property it is. Rather, it's part of the nature of mass that everything at least as massive as an electron has ϕ_m. However, given modalism, ϕ_m is wrongly counted essential to charge. Proving this result is simple. Given DE, it's metaphysically necessary that charged particles have ϕ_m. Where q denotes the property of being charged:

1. $\Box\forall x[q(x) \rightarrow \phi_m(x)]$

Now pick an arbitrary world w, and an arbitrary property P instantiable at w, and suppose that $\exists x[\mathrm{P}(x) \wedge \neg\phi_m(x)]$ at a world w' in the P(x)-neighbourhood of w. From (1) we can conclude that $\neg \mathrm{P} = q$, since

(1) says that q has no such instances at *any* world. Hence, since w and P were arbitrary, we have:

2. $\Box\forall \mathrm{P}[\neg\forall x\{\mathrm{P}(x) \mathrel{\Box\!\!\rightarrow} \phi_m(x)\} \rightarrow \neg\mathrm{P}=q]$

By contraposition, (2) entails:

3. $\Box\forall \mathrm{P}[\mathrm{P}=q \rightarrow \forall x\{\mathrm{P}(x) \mathrel{\Box\!\!\rightarrow} \phi_m(x)\}]$

According to modalism:

4. $\forall \mathrm{F}\forall\phi[\phi$ is essential to $\mathrm{F} \leftrightarrow \Box\forall \mathrm{P}\{\mathrm{P}=\mathrm{F} \rightarrow \forall x[\mathrm{P}(x) \mathrel{\Box\!\!\rightarrow} \phi(x)]\}]$

But from (3) and (4) it follows that ϕ_m is essential to q: the disposition to exert a force $F \geq \mathrm{G}M_eM_x/R_x^2$ on a mass M_x at separation R_x is essential to charge. If there's an asymmetry in the way in which charge and mass are related to ϕ_m, it's that some massive particles lack ϕ_m whereas no charged particles do, and that's clearly the wrong kind of asymmetry, because it suggests that ϕ_m is more closely related to charge than it is to mass.

4.2. Can Modalists Tidy Up Stray Essences?

Modalists may argue that the problem highlighted by the argument of (4.1) isn't with modalism, but the use of *bestowal* to define the causal roles of properties. The true causal role of a property, a modalist might suggest, is a proper subset of the dispositions it bestows. I think this is true, but will argue that given DE, the proper subset in question can't be specified without appealing to a primitive, non-modal concept of essence. Let us first consider whether there is a modal relation that will identify the proper subset in question. A *prima facie* plausible candidate is 'directly bestows'. Here are two candidate modal relations:

M1: $\forall \mathrm{F}\forall\phi[\mathrm{F}$ directly bestows $\phi \leftrightarrow \{\mathrm{F}$ bestows $\phi \wedge \neg\exists \mathrm{P}[\mathrm{F}$ bestows $\mathrm{P} \wedge \mathrm{P}$ bestows $\phi]\}]$

M2: $\forall \mathrm{F}\forall\phi[\mathrm{F}$ directly bestows $\phi \leftrightarrow \{\mathrm{F}$ bestows $\phi \wedge \Box\forall x[\phi(x) \rightarrow \mathrm{F}(x)]\}]$

(M1) says that F directly bestows ϕ iff F bestows ϕ and there are no intermediaries between F and ϕ; (M2) says that F bestows ϕ and directly bestows ϕ iff F ϕ is sufficient for F. Let '$\mathrm{M}^+{}_e$' denote the property of being at least as massive as an electron. *Prima facie*, both (M1) and (M2) entail that q doesn't directly bestow ϕ_m, while $\mathrm{M}^+{}_e$ does. Grant for argument that q bestows ϕ_m by bestowing $\mathrm{M}^+{}_e$. According to (M1), $\mathrm{M}^+{}_e$

directly bestows ϕ_m, but charge doesn't, since the route from q to ϕ_m goes via M^+_e, but between M^+_e and ϕ_m there is no intermediary. Although (M1) has the desired result, it's false on independent grounds. There are physical properties that bestow multiple dispositions which nothing else bestows. In such situations (M1) entails that the physical properties in question don't directly bestow any of the dispositions, since the dispositions bestow each other, resulting in a transitive route between the physical property and each disposition. Charge is a case in point. Consider the elementary charge e, which bestows a set of dispositions given by $F_{ij} = k_e e q_j / R_j^2$ upon its bearers. Now consider charges q_1 and q_2, at separation R_1 and R_2 respectively from a proton. Its charge e bestows upon the proton the dispositions (i) D_1: to exert $F_1 = k_e e q_1 / R_1^2$ on q_1 and (ii) D_2: to exert $F_2 = k_e e q_2 / R_2^2$ on q_2. Since *only* particles with charge e have either D_1 or D_2, and every particle with charge e has both D_1 and D_2, it follows that D_1 and D_2 bestow each other. But this means that according to (M1), e doesn't directly bestow either D_1 or D_2—e doesn't directly bestow D_1 since there is a property, D_2, such that e bestows D_2 and D_2 bestows D_1; similarly, *mutatis mutandis*, for D_2. Since e directly bestows both D_1 and D_2, (M1) is false.

According to (M2), M^+_e directly bestows ϕ_m but q doesn't, since ϕ_m is sufficient for M^+_e but not for q. This is because there are *un*charged particles with M^+_e and hence with ϕ_m. We can put the point equivalently by saying that ϕ_m *requires* M^+_e but doesn't require charge. However, (M2) is also false on independent grounds. This is because there are physical properties that *overlap* in the dispositions they bestow, and in such cases the dispositions in question aren't sufficient for any of the properties that bestow them. Colour charge is a case in point. Hadrons (e.g. protons) are composed of three quarks, held together by the strong nuclear force. According to quantum chromodynamics, quarks have one of three distinct colour charges, labelled red, green and blue. Similarly to the electric charge, unlike colour charges attract, but there are different mechanisms of attraction for the different colour charges. The force between quarks is grounded in colour charge and mediated by the exchange of *gluons*, which also carry colour charge. Setting aside the details, a red quark attracts a blue quark by emitting a red anti-blue gluon. In the process, the red quark becomes blue, and the blue quark absorbs the red anti-blue gluon, becoming red. In this way, colour charge is conserved. Similarly, a green quark attracts a blue quark in virtue of *its* colour charge—but in this case by emitting a green anti-blue gluon. The green anti-blue gluon is absorbed by the blue quark, which becomes green, once again conserving colour charge. What is important is that both red and green quarks are disposed to attract blue quarks, but this disposition is bestowed, respectively, by their red and green colour charges, which are distinct properties. This overlap is what refutes (M2), for the disposition to attract blue quarks isn't sufficient for either red or green colour charge, so we have to conclude, from (M2), that neither red nor green colour charge directly bestows it. Since both red and green colour charges directly bestow the disposition to attract blue quarks, (M2) is false.

If there's no defensible modal account of direct bestowal that correctly associates properties with their powers, perhaps we can appeal to a non-modal relation. Jessica Wilson offers a 'force-relative' account of the causal novelty of emergent properties, to deal with problems making sense of emergence given DE.[46] That fact that Wilson is concerned to properly divide up causal powers between emergent properties and their supervenience bases needn't concern us, for the reason why this is a problem is precisely that emergence is also, on reasonable assumption, metaphysically necessary if DE is true. For Wilson, the problem is that treating metaphysically necessary supervenience as a sufficient condition for a supervenient property to be nothing over and above its base entails that emergent properties are nothing over and above their Physical base properties, if DE is true of the latter. However, we could equally run the stray essences argument to show that anything putatively novel about emergent properties is essential to their base properties, and so not novel after all. The two issues are very closely related, and the solution I offer to the stray essences problem in part (5) could also be adapted to make sense of the possibility of emergence. Conversely, Wilson's solution to the problem of emergent properties might be adapted to the problem of stray essences. Wilson's key claim is that certain causal powers are grounded in fundamental forces: the power of like charges to repel is grounded in the electromagnetic force; proton-proton attraction within the nucleus is grounded in the strong nuclear force; and so on. Perhaps the powers essential to charge are those it bestows that are grounded in the Coulomb force.

Wilson's strategy, however, depends on the claim that the powers a property bestows are grounded in reified forces distinct from the property itself, and is therefore inconsistent with DE, according to which the causal powers a property bestows aren't grounded in *anything* other than the nature of the property. Indeed, if we reify forces, then as noted in (4.1), they too have dispositional essences and so exist *alongside* properties like charge in the ontology of Physics. If charge essentially bestows the disposition to exert a repulsive force on like charges, then that disposition is grounded in the nature of charge, just

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[46] Wilson (2002), pp. 70–75.

as the disposition to produce accelerations depending on mass is grounded in the nature of force. Suppose we treat the true causal role of property F as that proper subset of the powers F bestows that are *grounded in the nature of F*. Then we have:

$$\forall F \forall \phi [\phi \text{ is essential to } F \leftrightarrow \Box \forall P\{P = F \rightarrow [\forall x\{P(x) \mathbin{\Box\!\!\rightarrow} \phi(x)\} \wedge \phi \text{ is grounded in the nature of } P]\}]$$

I think there's something right about this account, but since the *nature* of a property *is* its essence, the concept of essence occurs on both sides of the biconditional. The point of combining modalism with DE in the first place was to provide a reductive analysis of the very idea that Physical properties have dispositional essences, and the above is no such analysis. If we must appeal to the essence of charge to define its causal role, then we can't reduce its essence to a causal role it has wherever it exists. I conclude that there's no adequate modal interpretation of DE. What does this mean for modalism? If the notion of essence in DE is the same as that employed elsewhere, then modalism is false *simpliciter*, and not merely unsuitable for framing DE. My argument can be recast so that it has the same form as Fine's, on the assumption that we can make sense of properties having properties. DE entails that charge necessarily has the second-order property of being a property that bestows ϕ_m on its bearers, but this isn't part of charge's dispositional essence. Hence not all necessary properties are essential, and modalism is false. One needn't endorse DE to argue against modalism in this way, because categoricalists can agree that even if DE were true, ϕ_m wouldn't be essential to charge. Although my argument has the same form as Fine's, it isn't susceptible to the strategy outlined in (3.1) as a reply to Fine, because being a property that bestows ϕ_m clearly isn't the sort of trivial necessary property ruled out by (MOD*).

5. Dispositional Essentialism II: Finean Essence

In this section I interpret DE using a broadly Finean account of essence.[47] The account: (i) is a form of primitivism about essence, (ii) treats essentialist claims by means of a sentential operator. The resulting theory will enable us to solve the stray essences problem, and offers a novel way of interpreting the claim that Physical properties have their causal roles essentially.

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[47] The theory is based on Fine's (1994, 1995a) remarks on essence, but I don't attribute it to Fine.

5.1. Finean Primitivism about Essence

Fine treats essentialist claims in terms of a sentential operator, 'true in virtue of the nature of the objects which F', which he represents as '$\Box_F$'. Fine defines 'F' using Lambda expressions appropriate to specific essentialist claims. For instance, 'it's essential to Socrates that he's a man' can be written '$\Box_F$ (Socrates is a man)' where $F = \lambda x.x = \text{Socrates}$. To avoid confusion with the modal operators of earlier sections, I use a different notation. I will also use variables rather than Lambda expressions to pick out the objects of essentialist claims, allowing these variables to range over anything about which essentialist claims can be made. I write 'p is true in virtue of the nature of x' as '$\Omega_x p$'. I only consider cases where p is a propositional function of x, and write '$f(x)$ is true in virtue of the nature of x' as '$\Omega_x f(x)$'. Every f such that $\Omega_x f(x)$ expresses a fact about x that contributes to making x what it is. In the simplest case $f(x)$ will be the subject-predicate sentence x is F, and in such cases it's natural to say that F is an essential property of x. Finean essence, however, is broader than the notion of an essential property, for it isn't mandatory to think of every f such that $\Omega_x f(x)$ as attributing a property to x. I will often speak of x as *truthmaker* of those propositions true in virtue of x's nature, but don't commit to the claim that all true propositions have truthmakers, or that truthmaking in general involves essences.[48] That modalism is false doesn't entail that essentialist operators lack modal implications.[49] Where $f(y/x) = f(x)$ with free y replacing every free x:

$$\text{MF: } \forall x \forall f[\Omega_x f(x) \rightarrow \Box \forall y\{y = x \rightarrow f(y/x)\}]$$

$$\text{PR: } \neg \forall x \forall f[\Box \forall y\{y = x \rightarrow f(y/x)\} \rightarrow \Omega_x f(x)]$$

(MF) specifies the modal implications of Finean essence, whereas (PR) gives the sense in which it's a primitivist theory. I assume (MF) without argument: if a function $f(a)$ is true in virtue of the nature of a, then necessarily, if any x is identical to a, then $f(x)$.[50] Like (MOD), (MF) entails that the essential properties of x are properties without which x can't exist. However, (PR) entails that there are entities such that not

48 This latter claim is, in my view, defensible, but I don't need to defend it here. See Cameron (2008).

49 I commit only to those principles I need. For a detailed study see Fine (1995b).

50 Zalta (2006) argues there are senses of essence in which even (MF) is false. Zalta, like Fine, offers a non-modal theory and logic of essence. However, Zalta's theory applies only to *objects* (concrete and abstract), and has no obvious application to essentialist claims concerning *properties*, causal or otherwise.

everything *sine qua non* is essential to them.[51] It is the lack of a sufficient condition for $\Omega_x f(x)$ that makes the current theory primitivist, and this carries over to individual essence. Let an individual essence of x be any (possibly improper) subset of the functions true in virtue of the nature of x, which aren't true of anything else. I denote such functions with '$\Omega^+{}_x f(x)$', and define the operator $\Omega^+{}_x$:

$$\text{IE: } \forall x \forall f\,[\Omega^+{}_x f(x) \leftrightarrow \{\Omega_x f(x) \wedge \Box \forall y[f(y/x) \;\rightarrow\; y = x]\}]$$

The occurrence of the primitive '$\Omega_x f(x)$' in the definiens rules out modal sufficient conditions for individual essence as well. Applying (MF) to (IE), we can easily deduce:

$$\text{MF}^+\text{: } \forall x \forall f\,[\Omega^+{}_x f(x) \;\rightarrow \Box \forall y\{y = x \leftrightarrow f(y/x)\}]$$

Principles (MF) and (MF$^+$) are direct analogues of (MOD) and (MOD$^+$) respectively. What distinguishes them is that the biconditionals of the modal principles are replaced by conditionals. Essentialist claims imply certain modal claims, but not *vice versa*. The operators Ω and Ω^+ characterise what we may term the *immediate* essence of an entity—that which makes (or contributes to making) it the entity it is, rather than another. Finean primitivism allows for weaker senses of essence than this. Of particular importance in the present context is what Fine calls *mediate essence*.[52] Suppose $\Omega_X p$, and in addition that p has a term referring to some entity $Y \neq X$, as in 'it's true in virtue of the nature of the electron that electrons have charge $-e$'.[53] Again following Fine, say that in such cases X *directly depends* on Y: electrons directly depend on charge.[54] But now suppose it's true in virtue of the nature of charge that charged particles emit electromagnetic radiation when accelerated. Charge then directly depends on electromagnetic radiation, but we aren't entitled to say the same about electrons. Rather, electrons directly depend on charge, which directly depends on electromagnetic radiation. What then is the relationship between the electron and the proposition 'electrons are such as to emit electromagnetic radiation when accelerated'? Let us say that this proposition is *mediately* true in virtue of the nature of electrons (where 'mediately' qualifies 'true in virtue of the nature of' rather than 'true'). Being an

51 Wide-scope negation allows for xs such that all the $f(x)$ true of x at any world where x exists are also true in virtue of the nature of x, but entails that there are some xs such that this isn't the case.

52 Fine (1995a).

53 I assume kind essentialism here for illustrative purposes only.

54 See Fine (1995a) pp. 61–2.

electron makes it true that a particle x has charge, and having charge makes it true that x radiates when accelerated. While there is a very close relationship between electrons and synchrotron radiation, it isn't as close as the relationship between electrons and charge—charge is part of the immediate essence of the electron, while synchrotron radiation is part of its mediate essence. The distinction between mediate and immediate essence isn't available to modalists, who must treat all necessary properties of an entity as related to it in the same way.

5.2. Finean Essence and the Problem of Stray Essences

In (4.1) I argued that modal interpretations of DE entail that ϕ_m—the disposition to exert a gravitational force $F \geq \mathrm{G}M_eM_x/R_x^2$ on any x at separation R—is essential to both charge, q, and the property of having mass equal to or greater than an electron, $M^+{}_e$. It's easy to show that Finean essence blocks the stray essences argument. As before, we can deduce:

1. $\Box\forall \mathrm{P}[\mathrm{P} = q \;\rightarrow\; \forall x\mathrm{P}(x) \;\Box\!\!\rightarrow\; \phi_m(x)]$

Proving (1) doesn't depend on modalism; it's a consequence of Finean essence too that if it's essential to charge that its bearers have $M^+{}_e$, then necessarily, charge bestows ϕ_m. However, (PR) entails that (1) is consistent with:

2. $\neg\Omega_q\forall x[q(x) \;\Box\!\!\rightarrow\; \phi_m(x)]$

(PR) expresses, in Finean terms, the claim that not all necessary properties are essential, and makes possible that charge necessarily bestows ϕ_m, but not in virtue of its nature. On this account, the set of dispositions charge bestows essentially is a proper subset of the set of dispositions it bestows *simpliciter*. That isn't to deny that charge depends on ϕ_m, because of course it does. The relationship between charge and ϕ_m is, I think, captured by the notion of mediate essence discussed above. If charge directly depends on $M^+{}_e$ and $M^+{}_e$ directly depends on ϕ_m, then charge *indirectly* depends on ϕ_m. Equivalently: if it's true in virtue of the nature of charge that every charged particle has $M^+{}_e$, and true in virtue of the nature of $M^+{}_e$ that its bearers have ϕ_m, then it's *mediately* true in virtue of the nature of charge that charged particles have ϕ_m. This strategy involves the admission that it's true in virtue of the nature of charge that its bearers have $M^+{}_e$. If, as suggested in (4.1), it's a law that the electron is the least massive charged particle, then—assuming such laws to be determined by the essences of Physical properties—we should accept this consequence. What would be problematic is the further claim that it's true in virtue of the nature of charge that its bearers have ϕ_m. (PR) prevents us deducing this, as it renders the maximally close dependency expressed by 'true in virtue of the nature of' intransitive. Charge depends in this way on $M^+{}_e$, and $M^+{}_e$ on ϕ_m, but we can't infer from this that charge depends on ϕ_m in the same way.

5.3. Dispositions and Truthmaking: Towards a Finean Conception of DE

We might express DE in terms of Finean essence by saying that for any Physical property P, there's a set ϕ of dispositions such that $\Omega^+{}_{\mathrm{P}}\forall x[\mathrm{P}(x) \mathrel{\Box\!\!\rightarrow} \phi(x)]$. On this view, the individual essence of P is a set of dispositions it bestows in virtue of its nature, and which no other property bestows. I'll call this *orthodox DE.* Fine's sentential operator approach to essence makes it possible to express DE without explicit reference to dispositions, by saying that for any Physical property P, there's a set L(P) of Physical laws such that $\Omega^+{}_{\mathrm{P}}\mathrm{L}(\mathrm{P})$. On this view, the individual essence of P is a set of Physical laws that are true in virtue of its nature, and which aren't true of any other property. I'll call this *Finean DE.* I aim in this section to argue that: (1) orthodox DE must treat Physical properties as truthmakers; (2) Finean DE is by far the more attractive of the two truthmaking theories.

In what follows, I assume a simple conditional analysis of disposition ascriptions, and so will argue that orthodox DE must treat Physical properties as truthmakers of the appropriate subjunctive conditionals. Once more, nothing turns on the conditional analysis being correct, and I assume it here for simplicity. The reason orthodox DE needs Physical properties to be truthmakers is that dispositional essentialists endorse a deflationary account of the laws of Physics as *propositions* whose truth is determined by the natures of Physical properties. Stephen Mumford, despite his eliminativism about laws, is prepared to accept that there are "...counterfactuals *made true* by the fundamental [dispositions]...."; such counterfactuals aren't laws, Mumford argues, precisely *because* Physical properties are their truthmakers, and so aren't governed by them.[55] Similarly, Brian Ellis takes laws to be propositions grounded in the dispositional essences of scientific kinds: "[i]n virtue of what is a law of nature true? The essentialist's reply is that laws of nature refer to the essential [dispositional] properties of natural kinds, and that these are their *truthmakers*."[56] The project of explaining (or explaining *away*) the laws of Physics as determined by the essences of Physical properties involves treating those properties as truthmakers. The idea dispositional

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[55] Mumford (2006), p. 464; italics mine. See also Mumford (2004).

[56] Ellis (2002), p. 102; italics mine.

essentialists share is that *qua* dispositional, Physical properties make subjunctive conditionals true, and we can deduce the laws of Physics from the conjunction of all the conditionals. Physical properties bestow sets of dispositions essentially by making the relevant disposition-defining conditionals true, i.e. $\Omega_P \forall x[P(x) \,\Box\!\!\rightarrow \{S(x) \,\Box\!\!\rightarrow M(x)\}]$.[57] But if orthodox DE is already committed to primitive truthmaking relations between Physical properties and *conditionals*, why not say instead that the primitive truthmaking relations are between Physical properties and Physical *laws*? I now argue that there are significant advantages to this way of thinking.

According to Noether's theorem, the symmetries exhibited by physical laws are associated with conserved quantities, hence conservation laws. For instance, under Newtonian mechanics, a particle moving at constant velocity has constant kinetic energy $E = \frac{1}{2}mv^2$. This law exhibits translational symmetry with respect to spatial co-ordinates, since velocity depends only on how far the particle travels per unit time, not which points it travels between. This symmetry entails conservation of momentum.[58] Similarly, in Quantum Electrodynamics, the dynamic equations for the electron are invariant under certain phase transformations of the electron wavefunction, and this symmetry entails conservation of electric charge.[59] It's a law that charge is conserved, but it's not obviously coherent to say that charge bestows the disposition to conserve itself come what may. Bird suggests that conservation laws and symmetries flow from the dispositional essence of the property of being a world, which the world obviously instantiates; Bigelow et. al. argue that such laws flow from the dispositional essence of the *kind* of world we live in.[60] But positing the property of being a world, alongside charge, mass and spin—or worlds as kinds, alongside electrons, quarks and photons—threatens the connection between metaphysics and physics that makes DE so appealing. It's also not clear what kind of disposition the world would need to have to ground charge conservation. Its manifestation is presumably that total charge is conserved; its stimulus, apparently, is anything you like. Given Finean DE, by contrast, we can

57 This statement should be read 'it's true in virtue of the nature of P that if any x had P, then it would be the case that if stimulus S happened to x, then x would M'. My argument that DE needs Physical properties to be truthmakers of conditionals applies equally if such properties are treated as identical to ungrounded dispositions. See Bostock (2008) for arguments that DE so interpreted treats the dispositions as truthmakers.

58 See Hanc et. al. (2004).

59 See Branding (2002) for a detailed historical study of the relationship between symmetries and charge conservation, and Livanios (2010) for an overview.

60 Bird (2007) pp. 213–4; Bigelow et. al. (1992). See Livanios (2010) for discussion.

say that charge conservation is true in virtue of the nature of charge without having to say its truth follows from dispositions charge bestows essentially, or from the essentially dispositional nature of anything else. As with orthodox dispositional essentialists, Fineans can see Physical laws as propositions whose truthmakers are Physical properties, but take this truthmaking relation to be fundamental rather than mediated by subjunctive conditionals.

An important issue arises at this point. Absent some account of the relationship between the claim that a certain law L is true in virtue of the nature of property P, and the claim that P essentially bestows certain dispositions, it isn't clear what's dispositional about Finean DE.[61] I will now argue that Finean DE about a property, at least in some cases, entails that the property essentially bestows dispositions. Charge is quantized, with all possible values being positive or negative integer multiples of the elementary charge, e (1.60×10^{-19}C). For this reason, I think it likely that e is fundamental, with other quantities of charge derivative. Coulomb's law as applied to charge e is: L(e): $F_i = k_e\, eq_i/R_i^2$. Assuming DE, we have: Ω_e[L(e)].[62] Let S(x) $=_{df}$ there's a particle y with charge e 1 nm from x; and let M(x) $=_{df}$ x exerts a force of $+2.30 \times 10^{-10}$N on y. From L(e) we can derive the determinate law:

$$\mathrm{LD}(e)\text{: } \forall x[e(x) \rightarrow \{\mathrm{S}(x) \rightarrow \mathrm{M}(x)\}]$$

Assume, with Fine, that Ω is closed under logical consequence.[63] Then we have:

1. Ω_eLD(e)

Consider an arbitrary particle a at the actual world, and consider what would be the case if it were the case that $e(a)$. From (1) and (MF), LD(e) holds at every world w_i in our $e(a)$-neighbourhood. Now consider what would be the case at each of the w_i if it were the case that S(a) there. Given weak centring, every world in the S(a)-neighbourhood of any w_i is a world where $e(a)$, since the closest $e(a) \wedge \neg\mathrm{S}(a)$ worlds to a

61 I thank an anonymous referee for this objection.

62 I ignore the fact that positive and negative elementary charge seem to be distinct fundamental properties. If so, then strictly speaking, L(e) will be true in virtue of *both*, since the q_i can be positive or negative.

63 Closure: $[\Omega_x p \wedge (p \Rightarrow q)] \rightarrow \Omega_x q$, where '$\Rightarrow$' indicates logical consequence. Fine subjects this to the constraint that q doesn't "involve objects which do not pertain to the nature of the given objects," Fine (1995b), p. 242. This prevents propositions such as '$\varnothing = \varnothing$' being true in virtue of the natures of every entity despite the fact they are logical consequences of every proposition. The cases I consider here don't violate this condition.

given w_i are closer to it than the closest $\neg e(a) \wedge S(a)$ worlds.[64] Once again, from (1) and (MF), LD(e) holds throughout the S(a)-neighbourhood of each w_i in our $e(a)$ neighbourhood. Hence, there are no worlds in the S(a)-neighbourhood of any w_i where $\neg M(a)$, from which it follows that $S(a) \;\Box\!\!\rightarrow M(a)$ at each w_i. But if it's the case that $S(a)^* \rightarrow M(a)$ at every w_i in our $e(a)$-neighbourhood, then:

2. $e(a) \;\Box\!\!\rightarrow\; [S(a) \;\Box\!\!\rightarrow\; M(a)]$

Since a was arbitrary, (2) entails:

3. $\forall x[e(x) \;\Box\!\!\rightarrow \{S(x) \;\Box\!\!\rightarrow M(x)\}]$

The derivation up to (3) depends only on the fact that LD(e) is true at every w_i in our $e(a)$-neighbourhood, and at every w_j in the S(a)-neighbourhood of any w_i. Define the w_k as all the worlds in $\{w_i\} \cup \{w_j\}$. That LD(e) is true at every w_k entails (3). But at each individual w_k, LD(e) is true in virtue of the nature of e. Assuming agglomeration[65] and closure under logical consequence, we may therefore conclude that:

4. $\Omega_e \forall x[e(x) \;\Box\!\!\rightarrow\; \{S(x) \;\Box\!\!\rightarrow M(x)\}]$

From $\Omega_e[L(e)]$, we can derive an infinite conjunction of sentences such as (4), which states that e essentially bestows the disposition to M when S. *That charge makes Coulomb's law true entails that it makes certain disposition-defining subjunctive conditionals true*.[66] It's natural to identify the dispositions a Physical property bestows essentially as those that are derivable, in the manner detailed above, from laws true in virtue of its nature. In (5.2) I argued that the primitivism of Finean immediate essence prevents us deducing that charge essentially bestows ϕ_m from the premise that charge necessarily bestows ϕ_m. We may now show that bestowing ϕ_m *isn't* essential to charge. Deriving that charge bestows ϕ_m involves (i) the claim that it's true in virtue of the nature of charge that bearers of charge have $M^+{}_e$, (ii) the application of Newton's law of gravitation to show that bearers of $M^+{}_e$ have ϕ_m. But Newton's law isn't true

64 The closest world where a doesn't have charge e and there's a particle with charge e 1 nm away is much further from each w_i than a world where a does have e, but there isn't a particle with charge e 1 nm away.

65 Agglomeration: $[\Omega_x p \wedge \Omega_x q] \rightarrow \Omega_x(p \wedge q)$. It's the conjunction C: 'LD(e) at $w_1 \wedge \ldots \wedge$LD(e) at w_k' that entails (3). We have: Ω_eLD(e) at $w_1 \wedge \ldots \wedge \Omega_e$LD($e$) at w_k. Agglomeration gives Ω_eC, from which, given closure, (4) follows.

66 Note that if Coulomb's law is *ceteris paribus*, the subjunctives derivable from it will be hedged, and the corresponding dispositions susceptible to finks and/or antidotes, depending on the *ceteris paribus* clauses.

in virtue of the nature of charge, so charge doesn't bestow ϕ_m essentially. Finean DE gives us a means of identifying the proper subset of the dispositions charge bestows that it bestows in virtue of its nature.

Despite all this, Finean DE entails neither that *every* Physical property essentially bestows dispositions, nor that those that do have dispositional *individual* essences. Call laws from which it can be deduced that properties that make them true essentially bestow dispositions *dispositional laws*. I think it unlikely that any Physical properties are truthmakers *only* for non-dispositional laws, but it's plausible that some are truthmakers for dispositional *and* non-dispositional laws. Suppose for argument that charge is truthmaker for both charge conservation and Coulomb's law, and that charge conservation is non-dispositional. Then charge doesn't have a wholly dispositional individual essence, as it seems there's a possible property, phlarge, whose dispositional nature is described by Coulomb's law, but which isn't conserved. I concede at this point that if DE must attribute *dispositional* individual essences to Physical properties, then my position isn't DE. However, I maintain, Finean DE captures everything that's important about DE. The point of saying that Physical properties have dispositional essences was to make sense of the claim that such properties have their causal roles essentially, but on reflection this notion of causal role is too circumscribed. What we should say is that *the causal roles of properties aren't exhausted by the dispositions they bestow*. I suggest a broader conception of causal role, according to which, for instance, being conserved is part of the causal role of charge. On this broad conception, we may retain the claim that Physical properties are individuated by their causal roles, despite the fact that they don't have *dispositional* individual essences. Like me, Vassilios Livanios thinks that the symmetries exhibited by Physical laws may be essential to the Physical properties those laws refer to, and that such symmetries can't be derived from dispositional essences.[67] Unlike me, however, Livanios takes this to refute the claim that Physical properties have *causal* individual essences, because he thinks that the symmetries of laws are independent of the causal roles of the properties they refer to.[68] Livanios is clear that symmetries, since they entail conservation laws, are empirically significant. We can predict, for instance, that any dispositions an electron has in virtue of its charge will be constant under the same transformations as those under which the relevant dynamic laws are invariant. Why, then, are symmetries independent of causal roles? Livanios seems to suggest

[67] Livanios (2010), esp. pp. 300–301.

[68] Stathis Psillos, in his, (2006) also argues that symmetry principles are independent of causal roles, but thinks of causal roles in terms of dispositions and their manifestations, which is what I'm suggesting we shouldn't do.

that this follows from the fact that symmetries are mathematical properties of laws that can be established without making measurements. But although we can identify symmetries and hence conserved quantities *a priori* from the mathematical structures of laws, the laws themselves are *a posteriori*: while symmetries in our descriptions of nature are *a priori*, that those descriptions are true isn't. Symmetries enable us to predict conserved quantities *a priori* only to the extent that they are symmetries in equations that truly describe our world. Indeed, some suggest that looking to see whether nature exhibits the symmetries predicted by equations is one way of testing whether those equations are true. That symmetry principles follow *a priori* from Physical laws doesn't make them independent of the causal roles of Physical properties.[69]

5.4. Finean DE, Scepticism and the Laws of Nature

I now argue that Finean DE meets all the desiderata of (2.3). Since meeting these desiderata is, by the lights of its proponents, what motivates DE, it follows that if Finean DE meets them, it's equally well motivated. Coulomb's law states that the force between charges q_i and q_j separated by R_{ij} is $F_{ij}=k_e q_i q_j/R_{ij}^2$. Let e denote the elementary charge, q_i and q_j specific integer multiples thereof, and let P range over quantized properties of which P_i and P_j denote integer multiples. Treat Coulomb's law as function of e that takes q_i, q_j and R_{ij} as arguments, and yields forces as values. Suppose for simplicity that Coulomb's law is the individual essence of charge: $\Omega^+{}_e[F_{ij}=k_e q_i q_j/R_{ij}^2]$. From this, together with (MF$^+$), we can derive a Finean analogue of (CH), which we used to rule out sceptical scenarios in (3.3):

CHF: $\Box\forall P[\{F_{ij}=k_e P_i P_j/R_{ij}^2\} \leftrightarrow P=e]$

The permutation sceptic imagines a world *w*P exactly like *w*A except that mass and charge exchange causal roles. But (CHF) entails that to imagine a property whose causal role is described by Coulomb's law *is* to imagine charge; ditto mass. (CHF) also entails that if we imagined a property identical to charge, then we imagined a property whose causal role is described by Coulomb's law; ditto mass. The duplication sceptic

69 Clearly there's much more to be said about this matter than I have space to say here. My point is merely to illustrate that there's no compelling argument from the fact that symmetries are *a priori* mathematical properties of equations to the conclusion that they are independent of causal roles. For more on the empirical significance of symmetries, including discussion of the distinction between symmetry in mathematics and symmetry in nature, see Kosso (2000); Branding and Brown (2004). For more on the physical interpretation of symmetries, and their role in quantum mechanics, see Castellani (2002).

imagines a world *w*D exactly like *w*A except that two properties occupy the charge role. But by (CHF), only one possible property occupies the charge role. The replacement sceptic imagines a world *w*R exactly like *w*A except that an alien property occupies the charge role. But by (CHF), necessarily, any property that occupies the charge role *is* charge. In each case, then, the sceptic simply imagines the actual world twice over, and misdescribes it. All sceptical scenarios are ruled out in exactly the same way as in (3.3), since the modal *implications* of Finean DE and modal DE are the same. What about laws of nature? Suppose there's a property Q at some world w, that's identical to charge e. It follows immediately from (CHF) that $F_{ij} = k_e Q_i Q_j / R_{ij}^2$ at w. Because this follows solely from the assumption that charge exists at w, there's no need to posit Coulomb's law as a second-order property distinct from charge. For the same reason, it's metaphysically necessary that charge has the causal role described by Coulomb's law. It's instructive to compare this reduction of laws with that offered by orthodox DE. Where '$\rightarrow_T$' indicates truthmaking, and '$\rightarrow_D$' derivability, orthodox DE can be depicted as follows:

O: [Physical property P $\rightarrow_T$ Subjunctives] $\rightarrow_D$ Laws featuring P

Orthodox DE is the claim that all Physical properties have dispositional essences, which, given the conditional analysis of dispositions, is represented by the truthmaking arrow. The derivability of laws featuring P entails, on reasonable assumption, that they too are true in virtue of P's nature.[70] Finean DE inverts the direction of explanation in (O): the fundamental truthmaking relation is between Physical properties and laws featuring them. That certain Physical properties essentially bestow dispositions is a consequence of the fact that they are truthmakers of dispositional laws:

F: [Physical property P $\rightarrow_T$ Laws featuring P] $\rightarrow_{D?}$ Subjunctives

In (F), DE is the claim that all Physical properties are truthmakers for whichever Physical laws refer to them.[71] Whether or not such properties essentially bestow dispositions depends on whether the laws they make true are dispositional. Orthodox DE requires all Physical laws to be derivable from dispositional essences, in which case all Physical laws

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70 Agglomeration and closure could would be required as with the converse proof in (5.3). I omit the details.

71 I ignore complications arising from laws featuring more than one Physical property. I have added a '?' to the derivability arrow in (F) because I don't think all laws of Physics are dispositional.

are dispositional. If so, the claim that Physical properties make the laws featuring them true, and the claim that they have dispositional essences, are mutually entailing, and there's nothing to choose between (O) and (F). However, conservation laws don't entail anything about the specific dispositions the conserved quantities they refer to bestow, and for that reason aren't dispositional laws, which is precisely why orthodox DE can't explain them in terms of dispositional essences. My approach removes the need to find dispositions to ground every Physical law, entails that (at least some) Physical properties bestow dispositions essentially, is as well motivated as orthodox DE, and—provided we don't limit causal roles to dispositions—captures the idea that Physical properties are individuated by their causal roles.

6. Conclusion

Dispositional essentialists must treat essence as a primitive, because modal DE mixes up causal roles between nomically correlated properties. On the assumption that dispositional essentialists don't have a non-standard sense of 'essence' in mind, it follows that modalism is false. Primitivism about essence doesn't reduce the epistemological appeal of DE, as the modal implications of Finean DE and modal DE are the same, and it's these implications that render sceptical scenarios impossible. A significant part of the appeal of DE consists in an ontologically deflationary account of laws of nature as propositions made true by the essential natures of properties. Orthodox DE accounts for laws in terms of dispositional essences, but this won't work without primitive truthmaking relations between Physical properties and subjunctive conditionals (or whatever propositions one thinks disposition ascriptions entail). Given the availability of Finean DE, it's not necessary to try to explain why the laws of Physics are true in terms of dispositions, which is a good thing, because certain apparently fundamental laws, such as conservation laws and symmetry principles, don't seem amenable to dispositional explanations at all. It's plausible that all causally individuated Physical properties bestow dispositions essentially, but not that all laws of Physics featuring those properties derive from the dispositions they bestow. Orthodox DE has the direction of explanation backwards. Those Physical properties that bestow dispositions essentially do so because they make the appropriate laws of Physics true, not *vice versa*.[72]

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