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The lawlike dynamics of tropes

A theory of natural laws in a one-category ontology

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Master's thesis in theoretical philosophy

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ABSTRACT

Trope theory is a philosophy that famously “calls for completion in a dozen directions at once.”¹ It is my intention here to walk some way one of these, where it, *prima facie*, seems that this theory might be in a worse position than the theory of universals. This subject is the one of *natural laws*, which due to their general nature might appear to pose a problem for any strictly particularist ontology. However, I will argue that, despite every trope's inherent particularity, we can still infer *universal* laws from them, if we correctly analyze what it means to *have a property*. This analysis leads us to an identification of the property-possession with the causal powers it infers. The theory is then employed in the analysis of Newtonian gravitation, in order to give a concrete example of its application.

¹ Williams: *On the Elements of Being*, p. 13.

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1. *The inquiry*

I am presently holding a pen in my hand, and I have been holding it for the last fifteen seconds. It seems perfectly possible to me that I could have dropped it five seconds ago, and that it then would have fallen. In other words, the sentence 'if I had dropped the pen at t , it would have fallen', when t is five seconds ago, is true. The purpose of this essay is to find an explanation of what makes this so.

A standard *physical* explanation of the process might proceed along the following lines:

- (1) The pen had, at t , a strictly positive mass.
- (2) There was, at t , a large mass fairly close to the pen, namely, the Earth.
- (3) Due to (1) and (2), *gravity* would have made the pen receive an acceleration towards the earth, that is, downwards.

The *metaphysical* question that will occupy us is what a natural law (in this case gravity) is, and how the existence of it can *make* (3) follow from (1) and (2).

1.1 *Constraints and foundations*

In the field of ontology, Dowe separates two tasks, which he calls the *conceptual* and the *empirical* analyses. The first of these is the semantic analysis of the meanings of metaphysical terms. The second is the analysis of the phenomena themselves.² This second task is what mainly will occupy us in the present essay.

Within this field, there is a large variety of possible standpoints to take. My intention here is to, so to say, hold a few of these variables fixed, and see what kind of theory we will be able to formulate in the realm of *natural*

² Dowe: *Physical Causation*, pp. 2-5.

laws. The points that I will keep fixed, and which will not be argued for here are these:

- (i) *A one-category ontology of tropes*. We will take everything that exists to be particular quality-instances, or tropes, or to be supervenient on these tropes.

I use the term *supervenience* in the same way that Armstrong does, i.e., “entity Q supervenes upon entity P if and only if it is impossible that P should exist and Q not exist, where P is possible.”³ Since every state of affairs discussed here is taken to be contingent, I will also sometimes simply write this relation as ‘P necessitates Q’, with necessity here taken to be *logical* necessity, in the sense that the negation of a statement expressing this relation results in a contradiction.

- (ii) *Realism about natural laws*. We will take natural laws to be real, objective constituents of the world. Given premise (i), this means that they will either have to be tropes, aggregates of tropes, or supervenient on any of these.

An *aggregate*, or *mereological sum* will be interpreted in the unrestricted sense, so that it is taken to supervene on its constituents. Thus, for any number of existent entities, there also exists every possible combination of these as an aggregate. These are not an addition to being; they are just different ways of looking at the things in question. A parallel might be drawn with the contents of a bowl of fruit: it might be said to consist of one orange, one apple and one banana, or alternatively, two yellow fruits and one green, or just a bowl of fruit. In any case the same things make all the statements true.

Theories that take laws of nature to be supervenient on particular matters of fact are usually not called realist, since the word is often reserved for those theories that take laws of nature to be something *more than* these facts (and most often relations

³ Armstrong: *A World of States of Affairs*, p. 11.

between universals). The laws being supervenient does not, however, make them any less real, just as my chair's being supervenient on its constituent atoms and their positions doesn't make it less real either.

(iii) *Laws support counterfactuals*. In order to be able to properly answer the question posed in the introduction, laws of nature will be assumed to give truth-conditions not only to questions about existent states of affairs, but also to certain *possible* states of affairs, like what would have happened *if* I had dropped the pen.

Dowe claims that an empirical analysis cannot be expected to hold in every possible world; that is, that we explicitly are dealing with the phenomenon *in this world*.⁴ However, it also seems reasonable to suggest that it should hold in worlds sufficiently similar to this one. Not because there needs to be such worlds, but because we don't *know* which world is the actual, and because all talk of counterfactuals would be empty if our analysis would not be valid, had things been different.

The aim of this essay could be described as an attempt to formulate some theory of laws, which a trope theorist might employ. I also hope that, in the course of this process, we might gain better understanding of what a trope is.

Something I regret that I do not have the space to discuss is the subject of probabilistic laws. This does not mean that I do not believe that there are such laws, or, for that matter, that all laws could be probabilistic. It is just a way of restricting the size of this inquiry. Hopefully, an extension of this theory into the probabilistic realm will not prove impossible.

1.2 Causation, laws and functional relationships

The metaphysical problem of natural laws is closely intertwined with the problem of causation. The distinction has sometimes been characterized as a

⁴ Dowe: *Physical Causation*, pp. 6, 96-98.

difference between tokens and types, where a singular causal sequence (like the dropping of the specific pen in the example above) is a token of the type (*law*) that, in the right circumstances, all sequences of this type would invoke identical effects.⁵

There is also a further distinction to be made. When speaking of laws, the most common example in philosophical literature seems to be ‘All Fs are Gs’. While this might correspond very well to laws used in some sciences, most physical laws are, as Russell points out, not like this.⁶ They rather resemble our example of the law of gravity, which tells us that two things’ masses give rise to an attractive force of a specified magnitude between them.

There is, however, not quite as large a difference as Russell claimed there to be. Mackie writes, in response to the call for an abolishment of causal laws (in Mackie’s terms *neolithic* laws) for a theory of functional correspondences (*functional* laws): ”a functional law will entail the holding of neolithic laws in appropriate fields”.⁷ For Armstrong a functional law is a *higher-order* law, from which first-order laws, like the correlation of two specific masses and a specific distance between them with an attractive force, can be deduced.⁸

In order to be able to answer the question posed in the first paragraph of this chapter, my main example of will be the general gravity law. The goal of this inquiry will thus be the concept of a *functional law*, which hitherto seems to have taken something of a background position in many other accounts of laws of nature. Nevertheless, as we shall see in chapter 3, thinking about functional laws provides several valuable insights for the treatment of non-functional laws as well.

⁵ Armstrong: *A World of States of Affairs*, p. 217.

⁶ Russell: *On the notion of cause*, pp. 194-195.

⁷ Mackie: *The Cement of the Universe*, p. 147.

⁸ Armstrong: *What is a Law of Nature?*, p. 114.

1.3 *The physical explanation*⁹

In order to isolate the relevant properties of the situation described in ch. 1, we will imagine a world with one spatial and one temporal dimension. In this world, there are two things: x and y . Each of these things has three properties: position, velocity, and mass. There are also two natural laws, of which the first is the general gravity law:

$$\text{L1: } F_x = F_y = G \frac{m_x m_y}{d^2}$$

Between every pair of things, with the masses m_x and m_y , being d spatial units apart, there is an attractive force of F on each of them. G is the general gravity constant, determining the strength of gravity in our world.

The second law is Newton's second law of motion, stating a correlation between forces and accelerations:

$$\text{L2: } F = ma$$

Here F is the force upon any thing, m the thing's mass, and a the acceleration incurred by the force.

We will also need two definitions, namely $a = dv/dt$ (acceleration is the rate of change in velocity over time), and $v = dp/dt$ (velocity is the rate of change in position over time). By using these definitions, we can see that gravity, over time, makes y acquire a velocity towards x . We will express this fact as a new law, even though this derivative third law follows from the conjunction of laws L1 and L2. It does, however, have the advantage of not requiring us to postulate the existence of any force-properties:

$$\text{L3: } \frac{dv_y}{dt} = G \frac{m_x}{d^2}$$

⁹ This explanation is largely of the kind prescribed by Hempel (e.g. Hempel and Oppenheim: *Studies in the Logic of Explanation*, pp. 137-138). As it is for Hempel, the possibility of logical deduction of the consequences from the initial conditions of the situation will be my intended goal. However, my characterization of properties as dispositions will make the notion of *natural law* reducible to these initial conditions as well.

Law L3 describes what would have happened in our first example, and thus our little test-world is at least rich enough to physically explain what happens when someone drops a pen. The question that now remains is what analysis we can give of such a law, employing nothing but tropes.

2. The interpretation of properties as tropes

The name *trope* was first used for the purpose we shall use it for here by Donald Williams, in his paper *On the Elements of Being*. Here, he declares them to be *abstract particulars*, very much like properties, but particular in nature instead of universal. We will take them to be *simple, abstract particulars*.

The simplicity of a trope means that it “does not contain (is not constituted of) more than one kind of entity.”¹⁰ Although this sounds reasonable, I will interpret the simplicity of the trope in a slightly different way, which is more along the lines of Bacon, who uses tropes as the basic building-blocks of the world.¹¹ These tropes *could* possibly be thought of as having parts, or *seen* as having them. The important thing is that we do not *need* to interpret them this way in order to describe the behaviour they impart on their possessor.

Abstractness is somewhat hard to define. Williams takes it to mean “*partial, incomplete, or fragmentary, the trait of what is less than its including whole.*”¹² Maurin suggests that we should interpret it as nothing more than *qualitative* (that is, like properties), to distinguish tropes from entities like Armstrong’s bare particulars, which are assumed to be absolutely propertyless.¹³

The particularity of the trope is what mainly sets it apart from most accounts of properties, which take these to be *universal*, that is, the same in

¹⁰ Maurin: *If Tropes*, p. 15.

¹¹ Bacon: *Universals and Property Instances*, pp. 6-7.

¹² Williams: *On the Elements of Being*, p. 15.

¹³ Maurin: *If Tropes*, p. 24.

every occurrence of them. A trope, on the other hand, is a unique entity, and can never be a part of two different things.

Two relations are further needed to connect our building blocks: similarity and concurrence. By similarity I will mean *exact* similarity. This is the relation that makes two colour-tropes (if there are such) the *same* colour. This relation, as Campbell has argued, introduces no new entities into the world. It tells us nothing that the terms in it did not already tell us, because it is impossible (logically impossible) for the colours to be what they are, and not be similar.¹⁴ It is thus supervenient upon the existence of its terms. For every trope, we can then define its *similarity-sum*, which is the maximal sum of all existent tropes that stand in this similarity-relation to that trope.

The concurrence relation, as sketched by Williams, is what binds a number of tropes together to form a thing.¹⁵ I will not go into the details of how this relation is manifested, but instead assume that, given a certain trope, we can somehow infer what other tropes that trope is concurrent with. Whether this requires the existence of a relational concurrence-trope, some substrate to tie the trope to, or nothing at all except the trope itself, is a question I will not go into here. Just as in the case of similarity, we can define an analogous *concurrence-sum* as the largest sum of all tropes that are concurrent with a given trope.¹⁶

2.1 Tropes as categorical properties

Armstrong makes a distinction between two conceptions of properties: the *dispositionalist* conception, and the *categoriclist*. The dispositionalist sees

¹⁴ Campbell: *Abstract Particulars*, p. 37.

¹⁵ Williams, *On the Elements of Being*, p. 7.

¹⁶ In order for this characterization of the two sums to work, we have to assume that the similarity-relation and the concurrence-relation both are equivalence relations. I find this a very reasonable assumption to make, but as Persson (*Two ways of sharing a property*, manuscript, 2003) has pointed out, there are some advantages to taking the concurrence-relation to be intransitive (for instance, that it would be possible to handle cases where the same property-instance is shared by two individuals, such as when two Siamese twins share one heart). Also, Bacon (*Universals and Property Instances*, p. 15) takes similarity to not necessarily be transitive, though this is probably mostly because he wants his tropes to correspond not only to properties but also to concepts.

a property as containing, in itself, everything that determines how it will interact with other properties. The categoricalist denies this, and takes the outcomes of these interactions not to be a product of the properties' natures, but of external relations between them.¹⁷

Armstrong himself defends the thesis that all properties are purely categorical. This means that the having of a property such as *mass* doesn't determine anything at all about how a thing interacts with other things. Instead, he places all the weight of truthmaking for statements such as our example 'this pen would have fallen if I had dropped it' upon the existent laws of nature.¹⁸ Given any set of properties, on this theory, it will still be contingent what laws their interactions adhere to.

Kistler points out that Armstrong's categoricalism runs counter to his heuristics for identifying the real properties of the world. This should, according to Armstrong, be done by the properties' causal powers, so that "(a) The active and passive powers of particulars are determined by their properties. (b) Every property bestows some active and/or passive power upon the particulars of which it is a property. (c) A property bestows the very same power upon any particular of which it is a property. (d) Each different property bestows a different power upon the particulars of which it is a property."¹⁹

Kistler accuses Armstrong, when he takes the laws of nature to be independent of what properties there are, of accepting a form of *quidditism*, that is, a belief in intrinsic, causally inefficient natures of the world's properties, since they could possibly be governed by completely different laws, and still be the same properties. As he notes, this is quite an obscure notion, and it also seems to contradict the spirit of scientific method.²⁰

Following Kistler, we can identify one problem with purely categorical properties: they say, by themselves, nothing whatsoever about the particulars that have them, and are thus in one way *unnecessary*. Being told that a thing has a certain mass doesn't allow us to infer *anything* about its behaviour, except in conjunction with the proper laws of nature.

¹⁷ Armstrong: *A World of States of Affairs*, p. 69.

¹⁸ *Ibid.*, p. 81.

¹⁹ Armstrong: *Universals and Scientific Realism*, vol. 2, pp. 44-45.

²⁰ Kistler: *The Causal Criterion of Reality and the Necessity of Laws of Nature*.

With laws of nature being this crucial for the categoricalist conception of properties, we might ask ourselves what account we can give of these. It turns out that several problems appear with many popular views.

Lewis takes a law of nature to be a theorem in the deductive system describing the world that achieves the best combination of simplicity and strength.²¹ This will not do for our purposes since, as among others Carroll has pointed out, it will make what laws of nature there are dependent on terms such as simplicity and fitness of combinations, which are hard to give a non-subjective analysis of.²² Thus Lewis's analysis will most probably not result in the laws being uniquely determined by the world's tropes, which was part of our assumption (ii).

Another view of laws of nature, which is instructive to study, is one independently advanced by David Armstrong, Michael Tooley, and Fred Dretske. This view takes laws of nature to be contingent relations of necessitation between properties.²³ Armstrong's main example of a non-functional natural law is 'All Fs are Gs', with F and G taken to be universals, and the statement as a whole as a statement of a higher-order fact. Armstrong expresses this fact as

$$N(F, G) \rightarrow (x) (Fx \supset Gx)^{24}$$

where x ranges over particulars, $N(F, G)$ means that there is a relation of nomic necessitation between the universals F and G, and this relation entails (but is not entailed by) the holding of the implications in all the particular cases. In his later works he explicitly identifies the relation N with the *causal* relation, generalized to relate types of states of affairs, instead of tokens.²⁵

However, on the one-category trope-theoretical view on the world, there *are* no universals, but only our *ersatz* universals, which are maximal similarity-sums of individual tropes. Can Armstrong's nomic necessitation be reinterpreted to relate these instead?

²¹ Lewis: *Counterfactuals*, p. 73.

²² Carroll: *Laws of Nature*, pp. 48-54.

²³ Armstrong: *What is a Law of Nature?*, pp. 88-93.

²⁴ *Ibid.*, p. 97.

²⁵ Armstrong: *Reply to Van Fraassen*, p. 422.

I can see two ways such a relation might be defined:

- (a) As a relation between *every trope that is F* and *every trope that is G*, or, in other words, a *single* multiterm relation between all the existent F- and G-tropes in the world.
- (b) As supervenient upon a class of relations relating every *pair* of F- and G-tropes, where the existence of the F-trope causes the existence of the G-trope.

Both of them, however, run into problems with our assumption (iii). For on reinterpretation (a), the existence of such a relation between every *existing* F-trope and every *existing* G-trope tells us nothing about F-tropes that *might* have been. And on reinterpretation (b), the same problem appears: what would make it true that, if we introduce a new F-trope, it will *necessarily* be concurrent with a G-trope?

I do not have the space to properly criticize the multitude of attempts that have been made to create working theories of natural laws, but it should be clear that any problem with defining natural laws independently of properties is equally a problem with the categoricist conception. Therefore, there is good reason to investigate the dispositionalist view.

2.2 Tropes as dispositions

Mellor defends taking all properties to be dispositions in his paper *In defence of dispositions*: “To be triangular is at least to be such that if the corners were (correctly) counted the result would be three. Inertial mass entails only subjunctive conditionals specifying acceleration under diverse forces.”²⁶ In our test-world, the mass of *x* necessitates its potentiality to be affected in specified ways by specific forces.

As Mellor notes, the possession of a disposition entails subjunctive conditionals. That *x* is soluble, for instance, entails but needs not be entailed

²⁶ Mellor: *Matters of Metaphysics*, p. 115.

by the conditional ‘If x were put in (enough) water it would dissolve’.²⁷ Though Mellor doesn’t believe that a full logical analysis can be given of this statement, it will still be useful for us in understanding the dispositionalist view. I will speak of the *antecedent conditions* as well as the *consequences* of dispositions, and I will mean the antecedents and consequents of the entailed subjunctive conditionals, which I will call the disposition’s *defining* conditionals.²⁸ Thus, the existence of the facts making up the antecedent conditions of a disposition’s defining conditional will, together with the existence of the disposition, necessitate the existence of the facts making up that conditional’s consequent. A dispositionalist theory of properties interprets *all* properties in this way.

This purely dispositionalist view has been criticized by Armstrong in several ways. First, a disposition is a property whose analysis contains a reference to a state of affairs that does not exist, namely the states of affairs that are the disposition’s antecedents. Mass, for example, contains references to all the forces that can possibly act upon it, even if some of these forces never actually occur. For Armstrong, who sees dispositions as relations, the existence of such a relation would mean that the antecedent conditions also have to exist (since the existence of a relation entails the existence of its relata). Since these, when the disposition is unmanifested, are merely *possible* and not actual, it appears that this would make us have to hold that that which is possible also exists.²⁹

Nothing, however, forces us to believe that the disposition is a relation. While we can sometimes describe it using a two-place predicate, this should not confuse us into thinking that it ontologically is a *relation*, just as our using a certain one-place predicate P shouldn’t make us believe that P has to correspond directly to some *property*. All of the dispositions that I discuss in this text are tropes, and not relations of any kind.

Armstrong’s second objection is that in a world where every property is a disposition, there does not seem to be any actuality at all; if everything is a

²⁷ Ibid., pp. 106-107.

²⁸ See ch. 3.1 for an exposition on the relationship between a disposition and its defining conditionals.

²⁹ Armstrong: *A World of States of Affairs*, pp. 79.

disposition to act in a certain way under certain circumstances, the product of the act will itself be another disposition. Everything will merely be *potential*, and nothing will be actual.³⁰

But this critique seems to rest on a misunderstanding. The “is” of a sentence such as “every property is a disposition” is the symmetrical “is” of identity, holding between the actual property and the disposition. Thus the property is not *less* of a property because it is a disposition, or a potential. For instance, while the property of weighing 1.0 kg *is* the potentiality to accelerate other things with a certain rate depending on their distance, to have this property is to *actually* have it. The potential and the actual are here merely different ways of describing the same state of affairs.

Mackie argues against the dispositionalist view on the grounds that it violates a principle of Hume’s, which says that there can be no logical connections between distinct existences. For, as Mackie writes, if a disposition is an intrinsic property of a thing, then the disposition, the antecedent conditions and the consequent would all be distinct existences, but the conjunction of the first two must entail the third.³¹

Persson, also an advocate of a largely dispositionalist theory of properties (although he prefers to think of them as *mechanisms* instead) notes that Hume did not state his principle as Mackie has claimed. Everything Hume’s original version says is that there can be no necessary connections between entities, which may exist *by themselves*.³² There can be good grounds for holding that one or some of the three states of affairs mentioned cannot do this. Persson points out that an effect that can be produced by a disposition, for instance, might nevertheless have existed without the antecedent conditions and without the disposition.³³

It seems to me that we could also accept Mackie’s version of the principle, and instead deny his premise that a disposition, its antecedent

³⁰ Ibid., pp. 79 – 80.

³¹ Mackie: *Truth Probability and Paradox*, pp. 137-138.

³² Actually, Hume’s main point seems to be that *anything* which is imaginable (which, on Hume’s account, is the same as everything that is possible), may be imagined on its own, and therefore also can exist on its own. Therefore, there can be no necessary connections *at all* between different entities (Hume: *A Treatise of Human Nature*, book I, part IV, sect. V, p. 233).

³³ Persson: *Causal Facts*, p. 130.

conditions, and its consequent are distinct existences. We do this by taking the consequent to *be* nothing but the conjunction (in the case of our tropes, the mereological sum) of the disposition and the antecedent conditions, since these will be able to function as truthmakers for all our statements about the consequent.³⁴

Trying to decide if we should interpret properties as categorical or dispositional, we can ask ourselves the question of whether it makes sense to stipulate that there can be anything to being a property, which is not given by the effects the possession of that property has. And if there is anything else, what can it be? Thinking about any physical property, I find myself quite unable to imagine what would be *taken on its own*, except the dispositions its possession incurs. There just seems to be nothing more to it.³⁵

While impossibility does not necessarily follow from unimaginability, these considerations do supply a reason for accepting the dispositional theory of properties. Further, when we interpret properties as tropes the dispositional theory has the advantage that it does not require us to assume the existence of laws as something other than the properties they involve. While it certainly might be possible to somehow represent independent laws in a one-category trope ontology, not having to do this seems like another substantial advantage.

2.3 Dispositional necessitation

Since the aim with this essay is to give a deductive explanation of certain laws of nature, I have written of the possession of a disposition in conjunction with its antecedent conditions as *necessitating* (that is, logically necessitating, as defined when discussing assumption (i)) its consequent. The idea that a disposition *must* entail some conditionals has, however, been

³⁴ In a completely deterministic world, we will then need nothing but the world's initial conditions to be able to give truth-conditions for any statement about it, anytime during its history. Of course, writing out an analysis of these conditions is quite likely to be either impossible or at least exceptionally impractical.

³⁵ I limit myself to speaking about *physical* properties, in contrast to *phenomenal* properties, since I *can* imagine, for instance, a quale apart from its effects. While this difference is certainly interesting, there is not space enough to properly discuss it in this essay.

criticized by Martin, who asks us to consider a live wire, connected to an *electro-fink*. This is a machine that turns off the current whenever a conductor touches the wire. If we now attempt to define the property of being *live* as the disposition to transmit electrical current to any conductor that touches it, the conditional ‘if this wire is touched by a conductor, current will flow from the wire to the conductor’ will not follow from this disposition, as the electro-fink will turn off the current in question.³⁶

David Lewis sets out to solve Martin’s problem of properly analyzing a disposition in spite of interrupting factors like the electro-fink. He notes the necessary condition that the disposition be *intrinsic* to the thing that has it, and that the thing that has the disposition *retains* it at least long enough for it to manifest itself. These conditions rule out dispositions having problems with the electro-fink.³⁷

Bird criticizes Lewis’s analysis, and points out that it still cannot deal with *antidotes*, that is, events that do not remove the disposition, but still somehow prevent the operation of it.³⁸ We will thus need a clause that says something like “provided that nothing stops the operation of this effect”, which Martin interprets as a *ceteris paribus*-clause. But, since there seems to be no end to the number of things that can interfere with a disposition such as *being live*, the only way in which we could specify these is by reference to the operation of the disposition. Thus no non-circular analysis is possible. Martin claims that this determines the role of such conditionals as nothing more than “clumsy and inexact linguistic gestures to dispositions”.³⁹

Mumford offers the solution that we should think of the *ceteris paribus*-clause as the operation under positive *ideal conditions*, which depend on the context that the disposition has been ascribed in. This will obviously make what sentences the having of a disposition makes true context-dependent. In most contexts, the presence of an electro-fink, for instance, hardly counts as ideal conditions.⁴⁰

³⁶ Martin: *Dispositions and Conditionals*, p.3.

³⁷ Lewis: *Finkish Dispositions*, p. 157.

³⁸ Bird: *Dispositions and Antidotes*, p. 228.

³⁹ Martin; *Dispositions and Conditionals*, p. 8.

⁴⁰ Mumford: *Dispositions*, pp. 87-92.

One problem with Mumford's solution is, of course, its context-dependence. The *ontological* question probably cannot be answered in this way, since it seems that what facts are *necessitated* by the existence of a certain disposition hardly can depend on the context we have ascribed that disposition in. In the case of the live wire, it must be the case that there *is* a determinate (although possibly infinite) number of things that could prevent the manifestation of the consequent. Although, in the infinite case, we cannot actually write this list out, this is a problem for logics and not for the ontological question of necessitation.

Another slight problem with Mumford's ideal conditions is that while they guarantee that the antecedent conditions are sufficient for the consequent, they do not say that these are *all* the sufficient conditions there are. We can consider an example with the dispositional property D, which has antecedent A, ideal conditions C, and consequent B. Suppose that A is true, and that the ideal conditions *do not* obtain, but that B still manifests itself. It can still be the case that A caused B, since C says nothing about what conditions are *necessary* for B. Indeed, we can sometimes have very good evidence for this, such as in the case where no other disposition that can cause B is present, and we still believe that *something* caused B. In short, the truth of C guarantees that B follows from A, but the falsity of C does *not* allow us to infer that A did *not* cause B.

My proposed solution to Martin's problem will be the conjunction of a sentence C (which will be referred to as the *ceteris paribus-sentence*) to the antecedent conditions, which is to be interpreted, loosely, as 'nothing interferes with the operation of this disposition'. As Martin has pointed out, it is circular, so this is not a logical analysis, but it can still be quite informational. For example, we can often determine whether C is true or false: if we independently have good grounds for believing that the antecedent conditions are true, and that the consequent manifested itself, we also have good grounds for believing C to be true. Likewise, if we have good grounds for believing that the antecedent conditions obtain, and also that the consequent has *not* been manifested, we similarly have good grounds for holding C to be false.

We can also write out *approximations* to C , which, while still containing unanalyzed components, may allow us to ascertain the operation of a disposition given a certain context. One such approximation might correspond to Mumford's ideal conditions. It should, however, be clear that this is just an approximation, and that an analysis employing nothing but positive ideal conditions often cannot be the whole story.

Finally, in some cases it *can* be possible to give an exhaustive analysis of C . If we allow ourselves to consider only states of affairs that are *physically* possible (which are taken to be among the states of affairs that involve only properties present in *our* world), it might be that several dispositions will have a C that can be written out using first- or higher-order predicate calculus. Since we are dealing with questions of laws of nature in our own world, this seems like a reasonable assumption to make.

Apart from the acceptance of the sentence C as a part of a disposition's logical analysis, my interpretation of dispositions is quite similar to Martin's. This means that I do not think that they, in the general case, are reducible to anything else. Since I have argued that properties are best understood as dispositions, and that properties are tropes, we reach the conclusion that every trope is a disposition. Our unanalyzable dispositions are thus nothing more than our basic building blocks of the world, which we assumed the existence of in (i).⁴¹

3. Building laws from singular facts

We will now attempt to give a characterization of natural laws that takes these to follow from the existent tropes of the world. As every trope is particular, a *law* must thus be something that is supervenient on or follows from the existence of these tropes.

⁴¹ More specifically, the dispositions we will be discussing are all tropes. This does not mean that *every* disposition is a single trope. For instance, it seems most probable that the ascription of a disposition such as 'irritable' in the sentence 'Jones is irritable' is made true not by the existence of a single trope, but by a very complex aggregate of them.

Mumford defends taking dispositions as primary, rather than laws, but interprets them as universals instead of tropes. His proposed thesis of *dispositional essentialism* says that, when we speak of the basic building blocks of nature, these are defined entirely by how they are disposed to act (which in Mumford's terms is the same as their *function*). Thus, an entity like an electron is what it is solely in virtue of its dispositions, and if it had acted differently under the same circumstances, it wouldn't have been an electron.⁴²

While Mumford's example of the electron might give one the impression that his essentialism pertains to *natural kinds*, this is probably nothing but the result of a poorly chosen example. In other parts of his book, Mumford explicitly interprets dispositions as *properties*, which on our theory will be taken to be tropes.

3.1 *The defining conditionals of dispositions*

I have argued that the possession of a disposition, contrary to what Martin holds, entails the truth of a number of conditionals, and, rather than simply being "clumsy and inexact linguistic gestures", we can, by analyzing the *ceteris paribus*-sentence to any given degree, make them as exact as we need to. The main purpose of this section will be to state some of the formal properties of these defining conditionals.

As tropes are *properties*, we define them by their effects on any thing x that has them. This appears to be the most natural way of defining a property as we, in general, cannot say anything about a specific property considered on its own, but only about *what it means for a thing to have that property*. A defining conditional for the tropes of a similarity-sum D will then be of the form ' $Dx =_{df} [(A(x) \ \& \ C) \rightarrow B(x)]$ ', where $A(x)$ and $B(x)$ are propositional functions which, given a thing x , yield the dispositional trope's antecedent A and consequent B , and where C is the *ceteris paribus*-sentence. The definition tells us that a trope, part of the concurrence-sum x ,

⁴² Mumford: *Dispositions*, p. 234.

is also part of the similarity-sum D if and only if the right-hand side (the *definiens*) holds.

The 2-place sentential predicate ‘ \rightarrow ’ must be identified with some stronger conditional than the material ‘ \supset ’, since we otherwise would have a lot more of these dispositional tropes in the world than it seems. Contrary to ‘ \supset ’, it is not entirely truth-functional, but also has the existence of the trope it is a defining conditional of as a necessary condition for its truth.

I will follow Mackie in linguistically interpreting ‘ \rightarrow ’ in the subjunctive mood, so that its truth-value may be undefined when A or C is false.⁴³ This should not make us think that the ontological feature of the world represented by ‘ \rightarrow ’ really *is* something subjunctive, as subjunctiveness is a grammatical and not a metaphysical notion. The term ‘subjunctive’ is used in an analogical way, and what is important about ‘ \rightarrow ’ is its logical properties. The foremost of these is that we define it as licensing the use of *modus ponens*, so that we are allowed to write ‘ $A \rightarrow B$ ’ only when the truth of A ensures the truth of B . For scientific purposes, it is also useful to note that this, of course, makes it falsifiable by exhibiting a false consequent in conjunction with a true antecedent.

We should note that ‘ \rightarrow ’ has a possible interpretation as *causation*, being a two-place predicate of ordered pairs of possible states of affairs. I would not, however, like to commit myself to the thesis that it always *is* causation, so I will render ‘ $A \rightarrow B$ ’ in English as ‘ A *nominally necessitates* B ’. The conceptual analysis, that is, whether ‘ $A \rightarrow B$ ’ properly captures the sense of what is usually meant by ‘ A causes B ’, will have to remain an area for later investigation.⁴⁴

⁴³ Mackie: *Truth Probability and Paradox*, pp. 105-108.

⁴⁴ As the label ‘nominally necessitates’ is used as nothing but a place-holder for a complete formal analysis (which I am afraid I will not be able to give here), I will not go into details about which kind of necessity we are speaking about. One interesting point of notice, however, is that if we take ‘ $A \rightarrow B$ ’ to be a strict conditional, we can define a nomic necessity operator ‘ \Box ’ from the usual equivalence ‘ $(A \rightarrow B) \equiv \Box(A \supset B)$ ’ (see e.g. Hughes & Cresswell: *A New Introduction to Modal Logic*, p. 195). But it is far from trivial how we in the general case should interpret a sentence such as ‘ $\Box A$ ’, since it may lack the conditional character that defines a disposition, and our introduction of the symbol ‘ \rightarrow ’ was closely tied to such use.

One reading of ‘ $\Box A$ ’ that appears to be compatible with our interpretation of ‘ $A \rightarrow B$ ’ is ‘there is a trope that makes A true, and makes A true in every world where it exists’. The resulting modal system will however have to be non-normal, since the rule of necessitation

3.2 Non-functional laws

We are now ready to discuss the problem of non-functional laws. An example of one of these is ‘all Fs are Gs’, that is, ‘ $(\forall x) (Fx \supset Gx)$ ’, where x in our theory will range over concurrence-sums, and Fx and Gx will be the sentences that some trope belongs both to the concurrence-sum x and to the similarity-sum F , and that it belongs both to x and to G , respectively.

As it is so simple, this law is not really a good example of the kind of laws that dispositions can give rise to. We can, however, still write out a defining conditional for it:

$$D1: Fx =_{df} (C \rightarrow Gx)$$

D1 should be read as the definition of what it is to be a trope of the similarity-sum F , or, in light of our discussion in 3.1, simply as a definition of the property F . It could be written out in English as ‘a trope f is a part of the similarity-sum F iff, for any concurrence-sum x , if f is a part of x , then, all other things being equal, the existence of f as a part of x nomically necessitates the existence of a trope g , such that g is part of x , and also part of the similarity-sum G ’. The phrase ‘nominally necessitates’ is necessary for ruling out cases where every trope of F just by accident happens to be concurrent with a trope from G . It is what makes this account of dispositions counterfactual-supporting.⁴⁵

According to D1, the only thing that is necessary for the manifestation of this disposition F is the truth of the *ceteris paribus*-sentence. In fact, if it really is the case that *all* Fs are Gs, the *ceteris paribus*-sentence can be

(from $\vdash \alpha$, infer $\vdash \Box \alpha$) cannot be valid in it, or even non-contingent truths would have tropes as truthmakers. In any case, the full analysis will have to wait.

⁴⁵ Carroll (*Laws of Nature*, p. 150) offers a convincing proof that realistic laws of nature cannot be supervenient on the *nonnomic* concepts used in describing the world. However, this does not contradict the present analysis, as he counts *counterfactual dependence* as a nomic concept, and the relation of nomic necessitation we are employing can be interpreted very well as such a dependence. In other words, we have not *reduced* the inherent modality of natural laws to something else, but only *reinterpreted* it to be an integral feature of the world’s properties.

replaced by the tautology, and the disposition will always be manifested.⁴⁶ It will therefore be somewhat odd to speak of F as a disposition at all, but it can still be useful to be able to treat it as some form of degenerate case.

Are there actually any laws such as ‘all Fs are Gs’ in our world? If we stick with our physical examples, it *is* a law that every sphere with the same mass and size as the Earth attracts objects at a rate of about 9.8 m/s² at its surface. We can then let F stand for ‘is a sphere of 6300 km radius which weighs 6 quadrillion kgs, and G be ‘has a surface gravitational acceleration of 9.8 m/s²’.

But even if we can form the law statement using our predicates F and G, it appears improbable that these should correspond to basic properties that are actually present in nature, since at least F obviously is conjunctive. We can, however, analyze F further, into F₁ and F₂, so that F₁ is ‘is a sphere of radius 6300 km’ and F₂ is ‘weighs 6 quadrillion kg’. The new law statement becomes ‘(∀x)[(F₁x & F₂x) ⊃ Gx]’, with G still defined as before. The dispositional tropes that are parts of the similarity-sums F₁ and F₂ can be defined by the pair of conditionals

$$D2.1: F_1x =_{df} [(F_2x \& C) \rightarrow Gx]$$

$$D2.2: F_2x =_{df} [(F_1x \& C) \rightarrow Gx]$$

which tell us that the tropes of F₁ are those that, whenever they are concurrent with any trope of F₂, nomically necessitate that they also are concurrent with a trope of G, and the tropes of F₂ are those that, whenever concurrent with a trope of F₁, nomically necessitate that they also are concurrent with a trope of G.

Of course, we cannot be sure that F₁ and F₂ denote basic properties of our world either, and G most probably doesn’t. And apart from this, there is another way in which ‘(∀x)[(F₁x & F₂x) ⊃ Gx]’ is unsatisfactory as an analysis of the general gravity law: it is simply not general enough. How does the law affect objects that are not exactly at the surface of the sphere,

⁴⁶ The question of whether there *are* dispositions in our world such that their *ceteris paribus*-sentences are always true is, of course, an empirical question. I will not go into it here, but only note it as an advantage of this theory of laws of nature that its descriptive power does not depend on whether there does or does not exist laws like this.

for instance? We could say that the Earth has several independent dispositions to accelerate objects - one for every possible height above its surface. But this does not properly reflect our intuition that it is the *same* thing that gives rise to all these conditionals - namely the Earth's mass. It also doesn't explain why they fit so neatly into a certain mathematical structure. To capture this, we need to be able to treat tropes as somehow interrelated, and dispositions as *functional relationships*.

3.3 Functional laws

Let us consider a thing x that satisfies two conditionals: one that makes it Q whenever it is P, and one that makes it S whenever it is R. Are these two entailments of the same dispositional trope, or entailments of different tropes? I will take the answer to depend on what kind of properties P, Q, R and S are, or more specifically, that they can be entailments of the same disposition only if P and R, and Q and S, pairwise, belong to the same *determinable*.

A determinable is a higher-order property of properties that *fall under* it. One such determinable is *mass*, which is a higher-order property of properties like *being 1.0 kg*, *being 2.0 kg*, etc. Armstrong, among others, takes all of these *determinate* properties to be logically exclusive.⁴⁷ That is, for every determinable, a thing can only instantiate a single determinate property that falls under it. The property of being a determinable is not a true, basic property, but is supervenient on the determinate properties. Thus a trope's being a *mass of 1.0 kg* entails that it is also *a mass*, or, differently put, that it belongs to the determinable-sum of mass.⁴⁸ Just as our *ersatz*

⁴⁷ I believe that Armstrong is basically right here, but I can offer no proof of this at the moment. A possible counterexample might be *force*, which, in order to avoid certain problems pointed out by Cartwright (*How the laws of Physics Lie*, pp. 57-62), it has to be possible for a thing to have several simultaneous instances of, which together determine a *net* force. In this essay, I will simply disregard such difficulties, as discussion of them would take us too far from the subject of natural laws.

⁴⁸ Armstrong: *A World of States of Affairs*, p. 48. Mellor (*The Facts of Causation*, pp. 208 - 209) also uses determinables in his theory, but doesn't explicitly claim that they have to be supervenient on determinate properties. I will take it to be impossible for any trope belonging to a certain determinable that it could exist, and yet be a member of a different determinable.

universals (the similarity-sums), its existence entails no increase in being. And just as with the relation of similarity, the existence of two tropes is sufficient as a truthmaker for whether they belong to the same determinable or not.

When discussing functional laws, the possession of a certain dispositional trope is taken to be able to entail not only one conditional, but any finite or infinite number of them.⁴⁹ In the case of the mass of x in our test-world, that mass-trope will entail a conditional for every possible combination of distance between x and any other massive concurrence-sum y . But it has to do even more; to be able to properly sustain counterfactuals, the mass-trope will also have to entail conditionals for all the other combinations of particles that *could* have been.

Armstrong gives as an example of a functional law the law $L: Q = f(P)$, stated as a relation between universals:

$$L: (\forall x) (\forall P) (Px \supset (\exists Q) (Qx \ \& \ Q = f(P)))^{50}$$

Here, x ranges over particulars, and P and Q are taken to be *values*, which Armstrong defines as a determinate property having some determinable property. In our interpretation of trope theory, these values are equivalent to similarity-sums whose constituent tropes are all part of the same determinable. P and Q thus range over all the possible determinate values that the determinable they fall under may have. The function f assigns a determinate property Q to each determinate property P .

As in the non-functional case, we will define a sum of tropes such that the law follows from this definition. Contrary to definitions like D1, D2.1 and D2.2, however, this will be a definition of what it is for a trope to be a part of a certain a determinable-sum, rather than of a similarity-sum:

$$D3: \mathbf{P}x =_{df} ((\forall P) [(Px \ \& \ C) \rightarrow (Qx \ \& \ Q = f(P))])^{51}$$

⁴⁹ This is not a full specification of what differentiates functional dispositions from non-functional ones, since *every* disposition that entails a conditional ‘ $p \rightarrow q$ ’ naturally also entails an infinite number of others, like ‘ $p \rightarrow (q \vee r)$ ’, ‘ $p \rightarrow (q \vee (r \vee s))$ ’ etc. Nevertheless, I hope that the difference is clear enough to the reader.

⁵⁰ Armstrong: *What is a Law of Nature?*, p. 111.

The boldface ‘**P**’ designates the determinable that the properties P range over. ‘**P***x*’ should be read as ‘some trope is part of the determinable-sum **P**, and also of the concurrence-sum *x*’. The property Q, determined by *f*, falls under its determinable **Q**.

One problem with the function *f* appears when interpreting properties as tropes: that it maps *sums* into *sums*, when these sums are really nothing but the individual tropes themselves. To properly describe *f* using nothing but tropes, we can reinterpret it. Call this reinterpretation *f**. In contrast to *f*, *f** does not map similarity-sums into similarity-sums, but individual tropes into individual tropes. It does, however, preserve similarity-sums in this mapping. That is, *f**(*t*₁) will be similar to *f**(*t*₂) if the trope *t*₁ is similar to the trope *t*₂. The reason for this is simple: for *t*₁ to be similar to *t*₂, it is necessary that they *produce similar effects under similar circumstances*. If they did not, we would not be justified in claiming that they *are* similar. And as we can write *f* as the composition of a function taking a similarity-sum into a trope of the given similarity-sum, the function *f**, and another function taking tropes into the similarity-sums they belong to, it is possible to define *f* without any irreducible reference to independently existing similarity-sums.

There is also another problem with *f*. A *function* is usually interpreted as a mapping from a set U to a set V, or, more specifically, as a subset of U × V where each element of U is paired with at most one element of V.⁵² The *function itself* thus appears to be a complex entity. How can it then be a part of the specification of a simple trope? For instance, if the set U = {a, b, c} and V = {d, e, f}, and the function is defined as {<a, d>, <b, e>, <c, f>}, where a - f are values of some determinable, we could just as well take D3 to define three different dispositions: one that makes *x* into d whenever it is a, one that makes it e when it is b, and one that makes it f when it is c. So

⁵¹ We should note that we have not assumed the existence of universals, or even of sets, by quantifying over properties, since these are *sums*, and thus supervenient on the individual tropes.

⁵² Of course, the function *f* in D3 has been taken to relate determinables, which on this theory are *sums*, and not sets. I do not know in what way this makes *f* different from functions as they usually are interpreted.

why should we believe that D3 defines a *single* kind of trope, which has all these effects?

Mackie notes a related problem with taking dispositions to be ontologically basic: how, if the having of a disposition just is the holding of a conditional to be true, can we speak of *multiply-manifested* dispositions, that make not one but several such conditionals true? As an example he mentions inertial mass, which is manifested both in the difficulty of setting the massive object in motion, and the difficulty of stopping it when in motion.⁵³

The answer to Mackie's question, as well as to my own, will have to be that we do *not* equate the disposition with its entailed conditionals, but merely define, or *describe* it with the aid of them. The disposition itself is something else, about which we know nothing but its defining conditionals. One reason why this has to be so is that the sets related by f possibly could be infinite. In that case, any attempt to separate every possible antecedent condition would fail.

We can see why this has to be so: for a function f whose domain is a continuum, even if we *could* list $f(P)$ for an infinite number of P , this is no guarantee that the function specified by this list really would *be* f . For, since the domain of f is a continuum, there exists (or can be constructed) another point between every two given points, even in the infinite case, that still will be unspecified. Thus the function f itself will have to be taken as primary, and its values at different points as entailments of this irreducible function.

But perhaps we still should ask ourselves whether we have abandoned the spirit of trope theory in accepting definitions like D3. It definitely *looks* complex, so how can it be a definition of a *simple* entity? After all, D3 is composed of several parts, namely letters and logical symbols.

However, the fact that the sentence used as definition of a trope is complex does not entail that the trope itself cannot be simple. I have already given an argument that, in some cases, the function f cannot be composed of its values at its individual points. But what of the rest of D3? Could, for instance, the antecedent, the conditional ' \rightarrow ', and the consequent of a trope

⁵³ Mackie: *Truth Probability and Paradox*, pp. 145-146.

be different parts? Armstrong's argument against dispositions gives one reason why not: it would make the merely possible antecedents and consequents into terms of an existent relation, and thus existent themselves, which would commit us to a realism of the possible. If this is not a position we would like to be forced into, we had better deny that the antecedent and the consequent of a dispositional trope are distinct existences. It is clear that they cannot exist by themselves, and perhaps this is sufficient ground for claiming that we should not take them to be distinct at all.

It is my belief that one of the most enlightening ways of looking at a dispositional trope is to see it as a *tendency to react in specific ways to given stimuli*. As the disposition in general is irreducible (due to the possible irreducibility of C , and because the function f could relate infinite sets), we cannot always *analyze* these patterns of stimulus-to-reaction, but this does not mean that we cannot *describe* them. It is for this purpose that definitions like D3 are useful.

Now, any non-functional law can be restated as a constant or piecewise constant functional law, and as we have seen that the function f is irreducible, there is good reason to take functional laws as primary, and non-functional laws as special cases of these. Any disposition might thus also be seen as something of a *function from possible antecedents to consequences*.

3.4 Explaining the falling pen

It is time to go back to our gravitational example, and, more specifically, to the law L3, as defined in ch. 1.3. A representation of this law in the current theory will make L3 follow from x 's dispositional trope m_x , as well as from y 's trope m_y . We will interpret the trope m_x as x 's disposition to exert a gravitational pull of a specified strength on any other concurrence-sum y that also has a mass. We define this specific trope by the following somewhat complicated conditional:

D4:

$$m_x x =_{\text{df}} (\forall y) (\forall P_x) (\forall P_y) [(P_x x \ \& \ P_y y \ \& \ P_x \neq P_y \ \& \ C) \rightarrow (A_y y \ \& \ A_y = f(P_x, P_y))]$$

Here, y ranges over concurrence-sums, P_x and P_y range over the similarity-sums that belong to the determinable *spatial positions*,⁵⁴ and A_y is a similarity-sum belonging to the determinable *accelerations*, determined by the function f . The 2-place predicate ‘ \neq ’ should here be interpreted as *dissimilarity* rather than as non-identity.

A tentative rendering of D4 in English would be something like: ‘the trope m_x is the trope that, provided nothing hinders its operation, whenever part of a concurrence-sum x , which also contains trope of any similarity-sum P_x belonging to the determinable of spatial positions, for any concurrence-sum y , with spatial position P_y , dissimilar from P_x , nomicallly will necessitate the existence of a trope belonging to the similarity-sum A_y , which also will be a part of y , and which is determined by the function f .’

The function f , determining the magnitude of the acceleration incurred by the mass-trope m_x , will map pairs of positions into the domain of accelerations, according to the following formula:

$$\alpha(A_y) = G \frac{m}{(\pi(P_y) - \pi(P_x))^2}$$

Here, G is the world’s gravitational constant, m is a constant specific to the trope m_x (more specifically, the number we read off a scale when weighing x), α is a function taking accelerations into real numbers, and π is a function taking positions into real numbers.⁵⁵

The acceleration-tropes produced by all of the concurrence-sum y ’s causal interactions then together determine the *net* acceleration of y . This

⁵⁴ I am taking spatial position to just be a trope here. A relationalist should feel free to expand the definition given to determine a class of spatial relations instead.

⁵⁵ The functions α and π are introduced to avoid having to discuss the ontology of mathematical objects here. They should not be interpreted as requiring any kind of Platonistic numbers, but can rather be said to map from similarity-sums of tropes into whatever we think numbers are. Both of these functions are specified to map any tropes belonging to the same similarity-sum, and only these tropes, into the same number. They also have to fulfil a number of other criteria, like the requirement that the value of the concurrence-sum of two mass-tropes be equal to the arithmetical sum of the values of the individual tropes.

net acceleration, together with y 's current velocity-trope, determines its new velocity-trope.

For the case of the falling pen, only two concurrence-sums are relevant. If we let the earth be x , its having just the mass-trope it has will entail the conditional specified. This in turn entails the statement that any other concurrence-sum y with a mass-trope (like the pen) will be accelerated towards it. We have thus produced a *metaphysical* explanation of why the pen would have fallen that supplements the *physical* explanation, as we set out to do.⁵⁶

If we now step back and survey what we have accomplished in this chapter, we shall see that most of what I have been arguing about here does not concern empirical matters. Chapter 3.1 to 3.3 serve as an introduction to the terminology we have used in ch. 3.4, in which this essay's only empirical claim appears: that if Newtonian mechanics had fully described our world, one part of my pen would be a trope which can be described by the definition D4, or, more specifically, that the pen has a part m_x , and another part x , that jointly satisfy the formula ' $m_x x$ ', as we defined it.

Since a property is defined by the effects the possession of it gives rise to, the general gravity law *as it is usually expressed* (that is, as a correlation between properties) somewhat surprisingly turns out to be analytic. On the other hand, the statement that it actually governs anything in our world is synthetic, and so is the every assertion of the form 'that thing has mass m '.

But while the law stated as a correlation between properties is analytic, it is synthetic if we express it as a relation between *things* instead, where the things are picked out by ostension, by exemplification, or by any other non-stipulative definition. Therefore, we still have good reason to call laws of nature *real*: they are real, existent patterns in the dynamics and behaviour of the world's things. And just as in the textbook example of supervenience, where patterns appearing in the image made up from a dot-matrix supervene

⁵⁶ A final, subtle point needs to be made regarding the counterfactual. In order for the physical explanation to have any meaning, we are assuming that we evaluate the counterfactual in worlds that have the same relevant laws of nature as ours. In our dispositional theory of properties, this means nothing but the fact that the pen and the Earth are assumed to retain their positional and mass tropes up to and including the time t , when I drop the pen instead of holding on to it, in every world we consider.

on whether each dot is there or not,⁵⁷ these patterns are supervenient on the singular interactions that constitute them. A *law statement* is a way of describing them by treating numerically distinct but similar tropes as parts of a structure given by the determinables these tropes belong to.

4. Concluding remarks

I have presented a theory of natural laws that takes these to follow from the definitions of dispositional tropes. This theory avoids certain problems with accounts like Armstrong's, in that it does not make us have to take the existence of laws as something more than the existence of the tropes that they govern. It is also more specific than Lewis's theory, in that it definitely makes the laws of our world supervenient on particular matters of fact.

An important, still largely unexplained term is the function f used in describing functional dispositions. While we have determined some of this function's characteristics, a thorough analysis might require the acceptance of other things than tropes in our world. Since, as I mentioned, most standard accounts of functions use the concepts of *classes* or *sets*, it is possible that we have to add these to our ontology in order to fully explain the behaviour a trope imparts on its concurrence-sum.

A more radical solution would be to abandon the standard functional analyses, and instead take *functions* to be the basic, unanalyzable building blocks of nature. This would require reinterpreting every property (that is, every trope) as a function. Still, if we accept the thesis that all properties are dispositions, the step to taking them to be functions does not appear to be that impossible, since the difference between functions and dispositions might be seen as one primarily of logical form. Of course, such a programme would be far too heavy to attempt to carry through in an essay like this.⁵⁸

⁵⁷ Lewis: *On the Plurality of Worlds*, p. 14.

⁵⁸ I am indebted to Johannes Persson, Anna-Sofia Maurin and Martin K. Palmé for their valuable comments, criticism and suggestions regarding this essay.

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