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THE CONTINGENCY OF PHYSICAL LAWS

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Abstract. The purpose of this paper is to explain the sense in which laws of physics are contingent. It argues, first, that contemporary Humean accounts cannot adequately explain the contingency of physical laws; and second, that Hume's own arguments against the metaphysical necessity of causal connections are not applicable in this context. The paper concludes by arguing that contingency is an essentially emergent, macroscopic phenomenon: we can understand the contingency of fundamental physical laws only through their relation to the distribution of macroscopic modal properties in the manifest world.

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According to the traditional empiricist accounts of laws, laws of nature are contingent in at least two senses. First, statements or propositions can express laws only if they are actually true, but, unlike mathematical propositions, they might be false.[1] Second, there could be true statements which share their logical form with statements expressing laws, but which are not 'lawlike'. Some are true, as it is somewhat misleadingly said, only by 'accident'.

In fact, in the classical empiricist tradition, contingency played a particularly important role in distinguishing laws of nature from the rules and principles of logic and mathematics. The latter were supposed to be known *a priori* and, partly for this reason, necessarily true. Laws of nature, in contrast, are subject to empirical tests and discovery. Thus, although the truth expressed by law-propositions is not merely 'accidental', it is nonetheless contingent.

However, it has never been entirely clear how the requirement of contingency can be satisfied in the case of fundamental physical laws. Physical laws, formally speaking, state functional, mathematically expressible relations among determinate values of certain determinable properties. This means, that they involve properties, and define connections among them, which are characterizable only in the language of mathematics with the help of equations. More importantly, many of the relevant properties which figure in such laws — masses, charges, forces — are not directly observable features of physical objects. And the precise content of the relevant properties can only be specified by the role they play in the respective laws.[2]

If physical laws are contingent, then it must be possible for them to be different. But what do we mean when we say that they might be different? How can we understand the distinction, or the connection, between 'gravitational mass' and 'inertial mass' without the laws in which they figure or without the theory of which the laws are parts? And if we cannot separate the truth of laws from the content of properties that figure in them, then how can laws of physics be contingent?

Some philosophers think that these questions have no answer, and hence the contingency of laws is an illusion. Laws of physics, if true, are true by metaphysical necessity. Traditional empiricists thought that only *a priori* truth can be necessary and, since laws of nature are not known *a priori*, they must be contingent. However, after Saul Kripke's influential work on modality (Kripke 1972), most philosophers have become convinced that propositions can express necessary truth, even if their truth is subject to empirical discovery. If *a posteriori* necessity is possible, perhaps physical laws should be understood as being necessarily true as well.[3]

In this view, laws of nature are metaphysically necessary because the instantiation of certain nomological properties can noncontingently determine an object's behaviour. Nomic properties can metaphysically entail how particulars instantiating them would behave in certain circumstances. Having a certain electric charge, for instance, entails how an object with that charge would interact with other electrically charged objects. The function of laws is to provide a mathematically exact description of these (actual and possible) interactions.[4] Laws of nature express then empirically discoverable necessary truth.

It seems to me, however, that this post-Kripkean approach to the necessity of laws just reconceptualizes the problem and does not answer it. The problem of contingency traditionally arose because physical laws seem to determine the content of nomological properties. In the more recent accounts, the laws follow by necessity from the nature of such properties. In both cases, it is assumed that nomic properties and the laws in which they figure are noncontingently connected. Necessitarians about laws suggest that this is sufficient to prove that laws of nature are not contingent after all. The earlier accounts saw it as a challenge to our intuitive conception of laws.[5]

In my view, the traditional approach was right. There is no reason to assume that there could be only one physics: the physics of our actual world. Thus, the conceptual and/or metaphysical connection between laws and properties cannot make laws of physics metaphysically necessary.

The purpose of this paper is to propose an account of how the contingency of actual physics should be understood. The most common way to explain contingency is to apply Hume's argument against the metaphysical necessity of causation to the laws of physics. However, I shall argue that contemporary 'Humean' accounts cannot explain the contingency of laws and that Hume's own arguments are not applicable

in this context. I suggest that contingency — just as causation, time, or special science laws — is an essentially macroscopic phenomenon: we can understand the contingency of fundamental physical laws only through their connection to the distribution of macroscopic modal properties in the manifest world.[6]

1. The Humean account of contingency

The standard account about the contingency of physical laws is the so-called Humean theory. A theory can, however, be Humean in different senses. If 'Humean' just means the claim that laws of nature are metaphysically contingent, then David Armstrong's theory of laws as higher-order relations among first-order universals is just as Humean as David Lewis's account, according to which laws supervene on the patterns of distribution of first-order, local properties.[7] But in a more specific sense, a theory about laws is Humean not because it considers laws to be contingent, but because of the specific ground or explanation of their contingency.

My main concern here is David Lewis's Humean theory.[8] Here is how Lewis summarizes the essence of his Humeanism:

> Humean supervenience is named in honor of the greater denier of necessary connections. It is the doctrine that all there is to the world is a vast mosaic of local matters of particular facts, just one little thing and then another. . . . We have geometry: a system of external relations of spatiotemporal distance between points. . . . And at those points we have local qualities: perfectly natural intrinsic properties which need nothing bigger than a point at which to be instantiated . . . All else supervenes on that. (Lewis 1986, pp.IX–X)

It might seem that the truth of Humean supervenience not only explains, but straightforwardly entails the contingency of physical laws. After all, such laws, like everything else, supervene on the arrangement and patterns of the distribution of perfectly natural intrinsic properties (PNIP for short). And *this* arrangement is an entirely contingent matter.

However, it is obvious that the kinds of properties the content of which is directly given to us in experience cannot provide the inventory of PNIPs. If not for other reasons, just because we cannot sense properties 'which need nothing bigger than a point at which to be instantiated'.[9] Thus, we need to explain what those properties are and how we can identify them. Lewis's response is that they are properties identified by physics.

> . . . "how things are" is fully given by the fundamental, perfectly natural, properties and relations. . . And we may reasonably hope that physics . . . will give us the inventory of all the perfectly natural properties and relations that ever appear in this world. (Lewis 1999, p.225)

If this is right, then the problem of contingency can be answered by the assumedly contingent distribution of PNIPs. Unfortunately, this cannot be the end of the whole story. For, as we have seen, if fundamental properties are identified by the laws in which they figure, then their co-instantiations or patterns of distribution along the temporal axis is *not* contingent. True, there might be other arrangements and distinct laws. But if fundamental physical properties owe their content to the laws in which they figure, there could be no arrangement of the *same properties* which display a different pattern. For if the laws were different, we could not talk about the arrangement of the *same* properties anymore. Hence, 'Humean mosaic' — the idea that the same elements can be rearranged so that they give rise to different patterns — cannot explain contingency.

Lewis and other Humeans are aware of this problem, and they have a response to it. Let us grant that the laws are formulated in a language that (at least partly) identifies the content of properties that figure in them. Yet, properties *qua* nomological properties — that is properties that can be identified only by their *role* in laws — might not be the 'perfectly natural', intrinsic properties on which everything else supervenes. Rather, they are second-order properties, in a somewhat specific sense. They identify a property by its role: by its contribution to the truth of those propositions that express the laws.

A role needs something that fulfils it, and PNIPs are precisely the properties which are supposed to do this. Role-properties are modal in the sense that their instantiation must imply where and when some other properties are instantiated. But it does not follow that PNIPs, their first-order realizers, need to have such implications as well. No one can be a murderer unless he caused the death of another person. And no one can be the victim of a murder without having been killed. In this sense, it is a conceptual necessity that the murderer of the victim must have caused the victim's death. But this does not imply that Oswald must, by conceptual necessity, have caused Kennedy's death. Oswald is not necessarily a murderer, and Kennedy is not necessarily a victim. Similarly, the ultimate metaphysical ground of laws is the arrangement of those maximally determinate, intrinsic, 'natural' properties which 'realize' these nomological properties. And the arrangement of such realizer-properties is an entirely contingent matter.

Physics helps to identify PNIPs by formulating laws: functional relations among the instantiations of nomological properties. But such nomological properties are second-order role-properties. The Humean explanation of contingency is then that even if the connection between laws and the second-order properties which figure in them are not contingent because role-properties are identified at least partly by the laws in which they figure, this is compatible with the contingency of laws as far as they supervene on the distribution of first-order properties. Since both laws and role-properties supervene on the distribution of PNIPs, laws themselves are contingent. If

the first-order properties were arranged differently, both laws and the second-order properties would be different.

A comparison between nomological properties and dispositions, like objects' fragility or solubility, can further elucidate the idea.[10] On the Humean account, when we ascribe a disposition to an object, we do two things. First, we say something about how the object would behave in certain specific circumstances. Fragile objects, for instance, would break when dropped. The connection between the ascription of the disposition to an object and our claims about its — possible or actual — behaviour is *not* a contingent matter. For something to be fragile just means to display the kind of behaviour which fragile objects would, if they were dropped.

However, a disposition must also have a 'basis'. For dispositions are second-order properties in the sense of being higher-order determinables: if an object is fragile, then it must have *some* specific sort of first-order property (e.g. crystalline structure) that is responsible for its breaking when dropped; though it need not have a specific one (objects with different crystalline structures can still all be fragile). Dispositions are second-order properties in the sense that 'being disposed to do something in certain circumstances' is the property of having some property or other which realizes the disposition in the object, and which is 'causally responsible' for its behaviour in the specific circumstances.[11]

Now, dispositional properties are *noncontingently* related to an objects' behaviour in certain circumstances, since it is that kind of behaviour that identifies (or 'individuates') them. If fragility would not be connected to the disposition to break when dropped, it had no content; or it had an entirely different content. However, and crucially, the Humean view is that the relation between the first-order property, which is the disposition's basis, and the objects' behaviour is contingent. For it is conceivable that objects with the same first-order properties behave differently; for instance, that objects having a certain crystalline structure which is *actually* the 'causal basis' of breaking, might never break even if they are dropped. Since dispositions' bases are non-dispositional, they are not conceptually/metaphysically linked to objects' behaviour.

Similarly, nomological properties are noncontingently related to the laws in which they figure, since the laws provide them, at least partially, with their content (or laws 'individuate' them, as it is often said).[12] The relation between the ascription of second-order, nomological *role-properties* and the laws in which they figure is not contingent. Nonetheless, laws are contingent because the distribution of the first-order realizer-properties can be different from their actual arrangement.

But the Humean account of dispositions can only be an analogy to the Humean account of laws, and the difference between the two cases is as instructive as are their similarities. What makes the Humean theory of dispositions at least initially plausible is that we *can* have a theory about how the role-properties and their first-

order realizers are connected; for instance, how the physicochemical constituents of objects can contribute to their macroscopic behaviour in certain circumstances. But we cannot have a theory about how the properties that are supposed to figure in the most fundamental laws are 'fulfilled' by 'first-order' non-modal properties. Hence it remains entirely unexplainable, and not only for contingent reasons, what they are and how they operate. What is then the theoretical or philosophical reason to postulate them?

2. Hume's argument

It is at this point where the historical Hume becomes important. Lewis is committed to what he calls the principle of 'Humean recombination'.[13] The principle claims that any two intrinsic, maximally determinate, 'natural' property of distinct determinables can be co-instantiated with any other such properties at the same spatiotemporal region; and that every distribution of such properties at time t must be compatible with any other distribution at any other instant in history. Thus, it is the principle of Humean recombination that seems to be the ultimate explanation of the contingency of physical laws.

As we have seen, on the Humean account, physical laws are contingent because the arrangement of those first-order properties on which 'all else' supervenes is not *modally constrained*. The distinction between second-order role-properties and first-order perfectly natural and intrinsic properties that realize them seems to ground contingency.

But does it? One would think it does only if we have some independent reason to assume that the distribution of first-order PNIPs is not modally constrained. But the postulation of the in-principle unknowable first-order properties does not seem to provide us with such a reason. As Lewis himself observes, given that the distribution of second-order nomological properties cannot uniquely determine the distribution of their first-order realizers, it is possible that infinitely many different distributions of properties at the first-order-level will satisfy the same nomological connections among properties at the second-order level (Lewis 2009). But then, what justifies the assumption that there *can* be some arrangements of realizer-properties that would give rise to different laws?

I would like to stress that my point is not to deny that there *might* be first-order realizer properties on which the distribution of the second-order nomological properties can supervene. There is no a priori way to prove that such properties do not exist. My claim is that they cannot explain the contingency of physical laws because we cannot understand *what it is conceived when* we say that we conceive of their being rearranged. 'Vast mosaic' is perhaps a nice metaphor, but nothing more. Conceivabil-

ity requires at least some initial grasp about the nature of the relevant properties. But it is exactly that which is lacking in the case of the allegedly 'fundamental', 'perfectly natural' properties.[14]

Can Hume come to the Humeans' rescue here? Despite some superficial similarities between Hume and contemporary Humeanism, not really. The first thing to note is that Hume does not seem to be interested in the question of laws, not to mention fundamental physical laws. In fact, the very idea of ontological fundamentality would not have made much sense for him. His aspiration — as the subtitle of the *Treatise* proclaims — was to introduce the 'experimental method of reasoning into moral subjects' and to provide a new foundation of 'the science of man'; the subject matter of which is the operation of our epistemic and moral capacities. Hume's contribution to the modern theories of laws has nothing to do with the few remarks he makes about them.[15]

His main contribution to the modern understanding of science was that he popularized, radicalized and somewhat reinterpreted the occasionalist tradition, according to which there is no causation in nature *if* causation is understood as an exercise of a modal property or power.[16] It is in this context that he applies his famous 'conceivability argument', which is the ground of the subsequent empiricists' conviction that 'natural properties' must be nonmodal. Hume introduced different versions of this argument at several (scattered) places both in the *Treatise* and later in the *Essay*, but the following two seem to capture best what *he* has meant to prove:

> But having already prov'd that the power lies not in the sensible qualities of the cause; and their being nothing but the sensible qualities present to us; I ask, why in other instances you presume that the same power still exists, *merely upon the appearance of these qualities*? Your appeal to past experience decides nothing in the present case; and at the utmost can only prove, that that very object, which produc'd any other, was at that very instant endow'd with such power; but can never prove, that the same power must continue to *in the same object* or (sic!) *collection of sensible qualities*; much less, that *a like power is always conjoined with like sensible qualities*. (1975(T) p.91, my emphases)

> The bread, which I formerly eat, nourished me; that is, *a body of such sensible qualities* was, at that time, *endued with such secret power: but does it follow that other bread must also nourish me at another time* ... (E p.34) ... It is confessed that *the colour, consistence, and other sensible qualities* of bread *appear not*, of themselves, *to have any connexion with the secret powers* of nourishment and support. (1975(E) p.37, my emphases)

Hume's conceivability argument is a kind of *modus tollens*. If causation were an exercise of powers and objects could have such powers, then it should be necessary that they display a certain form of behaviour. But it is conceivable, in any circumstances, that the same object behaves (will behave) otherwise than it actually does

(or will). Consequently, Hume concludes that the ground of beliefs about the unobserved is not rational inference from causes to their effects, but the 'propensity of the mind' to form expectations about the future on the basis of already experienced regularities.

But whatever we think about Hume's 'positive' account of causation as the ground of inductive inference, his 'negative' argument against the rationality of ascribing modal properties is certainly not sound. For even if his observation about what we can imagine — or conceive — is certainly correct, the conclusion about modal properties (powers, production, agency, energy etc.) does not follow. What Hume's examples show is only that *the distribution of sensible qualities* at an instant does not directly entail the distribution of modal properties at that or other instants. However, this does not prove that there is no rational ground to ascribe modal properties to objects. It is one thing to say that an object, conceived as 'a collection of sensible qualities', can behave differently on different occasions. It is quite another that we have no rational ground to ascribe powers to objects; where powers are, roughly, dynamical modal properties the possession of which can 'necessitate' objects' behaviour and interactions in certain type(s) of circumstances.

What does follow from Hume's example is only that we can conceive that objects, understood as 'collections of sensible qualities', can lose and acquire powers, just as they can lose and acquire certain sensible properties. An object can grow, change its shape and color, or start to smell badly. Similarly, an object can acquire and lose its flexibility, hardness, fertility, etc. Paradoxically, Hume's 'conceivability argument' supports, rather than undermines, our natural practice to ascribe modal properties to objects, because it proves that objects *can* change in ways that *cannot* be captured by their merely qualitative properties. Moreover, we often distinguish (kinds of) object with reference to their modal properties. Phenomenally very different dogs have the power to interbreed, phenomenally very similar cats and dogs do not. *Aqua Regia* is not phenomenally distinct from many other acids: but it can dissolve gold.

Thus, Hume's ultimate reason to reject modal properties must be entirely different from arguments about conceivability. And indeed, it is. His ultimate reason is that we do not have an 'impression' about 'powers'; that is to say, objects' modal properties are not directly revealed or manifested to us in our experience. But first, this is just to restate what needs to be proved: that it is not rational to ascribe to objects properties which we cannot directly see, hear, smell etc. And second, and more important for us, this can hardly serve as an argument about the modal character of fundamental physical properties, since, whatever else they might be, these properties are not 'observable qualities'. Rather, they are supposed to be the nonsensible explainers of what we experience.

3. Contingency and fundamentality

Consequently, Hume's argument against powers and necessary connections cannot support the (contemporary) Humean account of the contingency of physical laws. For his argument cannot shed any light on the nature of properties assumedly composing the 'Humean mosaic' and, certainly, it cannot prove that they *must* be nonmodal. This seems to me a crucial issue because the Humean view that fundamental physical properties must be 'qualitative' — in the sense which entails that they cannot be modal — is largely based on Hume's arguments against 'secret powers'.

Of course, I do not mean that all this proves that 'fundamental, natural' properties must be modal. But this does show that *if* the dynamical/modal properties as identified by the laws of physics are not first-order properties and hence they need a 'fulfiller', then we do not have any clear idea of what *those* fulfillers are. We can insist that such properties must play a role in our account of physical reality. After all, our ordinary views of properties are the results of how we experience the world; in Sellars's influential terminology, they are rooted in the 'manifest image' (Sellars 1963). And what we learn from the world's manifest image can perhaps reveal very little about its fundamental nature.[17] But the postulation of such properties cannot explain the contingency of laws. For the claim that some *in-principle* unknowable properties can be recombined without any nomic restriction is entirely *empty*. In order to understand how the laws could be different, we should say how the first-order nonmodal properties need to be changed or rearranged in order for the laws to be different. But of this, we do not, and *cannot*, have any idea.

What I wish to propose is that our conception of contingency, Humean or not, is essentially tied to the 'nonfundamental', macroscopic world. It is the idea that the course of events *with which we are familiar in our life* can be entirely different from how they actually are. For it is certainly conceivable that bodies as observable physical objects might have different modal properties, and hence display different behaviour than what they actually do. It is conceivable that the behaviour of macroscopic physical objects or the nature of macroscopic physical processes might be different. Thus, instead of trying to understand contingency by the fictious 'Humean mosaic' of first-order 'qualities', we should explain it with reference to the world which we can directly experience.

Hume's examples do show how easy it is to imagine that objects in the manifest/macroscopic world might have different powers than what they actually seem to have. Objects that are painted red fall when they are unsuspended just as any other objects do. But we can easily imagine worlds in which, if painted red, unsuspended objects levitate rather than fall. We can imagine that the Sun rises at different places on the horizon every day, sometimes east, sometimes north and sometimes south. At least *prima facie*, all this does not seem to be inconceivable and hence impossible, be-

cause we more or less *know what we conceive*, unlike in the case of the rearrangement of properties with some entirely unknown nature.

Laws must explain that which we observe, thus laws should be different if our observations were different: is this not a trivial claim? It might sound trivial, if we read it epistemically: the test of the truth of the laws, at least partly, how they can explain the observed behaviour of objects. But my claim is metaphysical, and not epistemic.

Suppose that laws of nature are *not* contingent. Then it follows that we *could not* experience the world differently, even if we think we could. For a long while we, humans, thought that water is an element rather than a chemical compound. So, it seems it must have been conceivable that water is an element. Yet, many argue, following Kripke, that it is metaphysically impossible that water be an element. Perhaps it is also metaphysically impossible that physical objects have different powers and display different regularities in their behaviour than what the actual laws of physics identify. Denying that this is the case is not a trivial claim, it seems to me.

My claim is that if laws of nature are contingent, they are contingent in virtue of the contingency of the manifest/macroscopic world. Contingency is an essentially higher-level phenomenon. It is not to be explained in terms of ground level properties, but in terms of what supervenes on them.

Laws and properties come and go together. Nomological properties figuring in the laws of physics are modal properties by their nature: properties the instantiation of which does have implications with regard to which other nomological properties are instantiated at other spatiotemporal regions. But they are not *ontologically prior* to the manifest/macroscopic properties and regularities which they explain. Their role is to explain the fundamental *physical* structure of the macroscopic world and the world as it appears to us. If the world would be (radically enough) different at the manifest/macroscopic level, the laws and the nomic properties would be different as well. The ultimate ground of the contingency of laws is therefore that there is a manifest/macroscopic world.

It might be objected that whether or not the contingency of the manifest world can explain the contingency of fundamental physical laws depends on which laws we have in mind. For laws can be fundamental in two rather different senses. Some laws of physics might be considered as fundamental in virtue of their role in physical theory. Some conservation laws, for instance, seem to be fundamental in this sense; as are some laws about gravitation.[18] In this sense, laws are fundamental if they universally apply to every physical system *qua* physical; or if *more restricted generalizations* or laws can be derived from them. It is in this sense that the special and the general theory of relativity are fundamental given that, if certain specific conditions are satisfied, the laws of classical mechanics can be derived from them.

But fundamentality can also be understood compositionally. Macroscopic bodies

can be decomposed into molecules, which are composed of atoms, which in turn are composed of even smaller, 'fundamental' physical particles; and even further — as in Lewis's account — the distribution of the compositionally ultimate particles might be determined by the patterns of distribution of the PINPs. Then physical laws are fundamental if they are laws about the behaviour of particles with certain fundamental properties at the 'ultimate' or smallest scale.[19] Fundamental laws are laws about the behaviour of 'ontologically fundamental entities'.

These seem to be two rather distinct notions of the fundamentality of laws and, correspondingly, about fundamental properties. In one sense, a law is fundamental because it is a law about the behaviour of ultimate particles, or rather about how properties at the smallest scale are distributed; in the other sense, it is fundamental because other laws can be derived from it.[20] If we understand the fundamentality of laws in the latter sense then, it might be argued, my suggestion about the manifest world's primacy sounds plausible. For if generalizations about objects' observed behaviour and powers would be different, so should be the most generic laws from which they logically follow. But this has nothing to do with the 'ontologically fundamental'; that is to say, with laws and properties which are supposed to be the ultimate metaphysical determinants of the behaviour of objects in the manifest/macroscopic world.

My point is, however, that the meaning of fundamentality is not distinct in the two cases. What makes a law fundamental is its role in the explanation of the manifest/macroscopic powers and generalizations. Laws about the structure and behaviour of fundamental particles are contingent in the same sense, and for the same reason, as conservation laws or laws about gravitation are. If the manifest/macroscopic world were (radically) different, then the laws and properties that apply to the microscopic world must be different as well. The contingency of laws at the 'fundamental level' cannot be understood as the possibility of 're-designment of the Humean mosaic', but only with reference to the resulting, supervenient manifest/macroscopic world.

Given supervenience, the microscopic laws and properties must be different for the manifest/macroscopic world to be different. This is often interpreted as a claim about the ontological priority of the microscopic. But the supervenience of the manifest/macroscopic world on the microphysical laws and properties does not imply such ontological priority. It can also be interpreted as a claim about how the manifest/macroscopic *constrains* the laws and properties at the smaller scale. Only those laws *can* apply, and those properties *can* be instantiated, at the 'fundamental' (that is, micro-physical) level which together guarantee the occurrence of the existence of the relevant manifest/macroscopic properties and regularities.

In Chapter 6 of his posthumously published work *The World* Descartes tells an imaginary story about how God creates a material world (not necessarily ours). Imag-

ine, says Descartes, that all God creates is an infinite amount of matter, and that then he establishes a few fundamental laws about its motion. Then Descartes invites us to imagine that

> God has established these laws in such a marvellous way that *even if we suppose he creates nothing beyond* what I have mentioned, and sets up no order or proportion within it but composes from it a chaos as confused and muddled as any the poets could describe, *the laws of nature are sufficient* to cause the parts of this chaos to disentangle themselves and arrange themselves in such good order that they will have the form of a quite perfect world — a world *in which we shall be able to see* not only light but also *all* the other *things, general as well as particular, which appear in the real world*. (Descartes 1985, p.91, my emphases)

Although Descartes interprets his scenario historically — how an ordered world can develop from the chaos — I suggest that it can also be interpreted structurally, as an explanation of the relation between laws and properties at the minute scale and what supervenes on them. First and foremost, God *wants to create a macroscopic world with certain apparent characteristics*. All he needs to do in order to create such a world as it appears to us with bodies, their motion and their powers is to create 'matter'; or matter and the laws of motion, if the latter do not follow from the essential properties of matter.[21]

With reference to Descartes's story, we can reinterpret the metaphysical significance of supervenience of the manifest/macroscopic on the microphysical laws and properties. The basic idea is this: in order for the macroscopic, manifest world with certain objects, powers and regularities to exist, a specific set of 'fundamental', microscopic nomological properties needs to be instantiated. The pattern of their instantiation is metaphysically constrained in two ways. First, by the laws in which they figure; and second by the manifest/macroscopic world the structure and operation of which they subserve, as it were.

If laws and nomological properties at the fundamental level are neither conceptually nor metaphysically independent, then the contingency of fundamental laws cannot be understood with reference to different possible distributions of the nomological properties themselves. For a different distribution must still give rise to the same laws. But this need not entail that laws of physics are not contingent. We need to make sense of the idea that *both* fundamental properties and laws could be different. I argued that this can be understood only with reference to how the world would turn out macroscopically if they were different.

In a sense, fundamental laws are contingent only because of the contingency of the manifest/macroscopic world which surrounds us: the world at a scale at which physical bodies, their powers and their observable features and behaviour emerge. If such a world is 'only mere appearance', then perhaps contingency is only apparent as

well. But if it is as real as it appears to be, then its apparent contingency can explain the sense in which fundamental laws of physics are contingent as well.

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Notes

[1]For classical empiricist accounts of laws see Ayer 1956, Goodman 1955 and Hempel 1965. I assume that laws must be true at least *ceteris paribus*. If all propositions expressing laws are false, then it seems that there are not any laws in the metaphysical sense. Scepticism about laws is, of course, a possible option, and some philosophers endorse it for rather different reasons. See, for instance, van Fraassen 1987 and Mumford 2004.

[2]Kneale 1949 and Nagel 1961 saw the problem, as did Sellars 1948. The modality of laws was a central topic among the New-Kantians in the Margburg School, see especially Cassirer 1910.

[3]This view, called 'dispositional essentialism', is originally motivated by Shoemaker 1980 and 1998; even if Shoemaker does not seem to have been interested in nomological properties. The view has been then developed in different forms by Ellis 2001 and Bird 2007. Swoyer 1982 is a more direct application of Kripke's arguments to laws of nature.

[4]It is of course less clear how this idea is applicable to other sorts of physical laws, like exclusion laws, conservation laws or some laws of statistical mechanics, as is admitted by Bird 2007, Chapter 10.

[5]For further arguments against the necessity of laws see, among others, Sidelle 2002.

[6]About time, special science laws and causation as emergent phenomena see Loewer 2011.

[7]Armstrong holds that the relation between the relevant universals is 'contingent necessitation'. 'Necessitation' distinguishes laws from accidental connections; but necessitation is 'contingent', because laws are not *metaphysically* necessary. Since my concern here is metaphysical necessity, Armstrong can be classified as 'Humean' in this respect. See Armstrong 1983.

[8]As Loewer 1996 argues, Lewis's theory seems to fit best with what physics actually does. However, part of my arguments apply, *mutatis mutandis*, to other broadly Humean accounts as well.

[9]Whatever 'minima sensibilia' are, they are not points; certainly not in the sense in which point masses or being a kind of point particle are properties, instantiated at one specific spatiotemporal point.

[10]In fact, Lewis in his last work does hint to that analogy, see Lewis 2009. Earlier Mackie, otherwise a Humean in many respects, admitted that most nomological concepts are 'dispositional' (which means that they are modal); although he thought that this is only a temporary feature of the not yet fully developed science. See Mackie 1977.

[11]Elements of this account can be found in Mackie 1977 and later in Prior, Pargetter and Jackson 1982. Lewis's own view of dispositions is also a version of such accounts, see Lewis 1999, pp.140–51.

[12]I prefer to say that the content of a property is determined rather than 'individuated', since, intuitively, we individuate individuals, that is, *particulars*, and not properties.

[13]The principle is developed in Lewis 1986a.

[14]For how this problem arises in the context of the Best System Account of laws, see Loewer 2007.

[15]In fact, on the few occasions when Hume seems to address the issue of laws of physics, his arguments are rather confusing. In order to reconcile his system with Newtonian physics, Hume says that we directly experience *vis inertiae* (that is to say, inertial mass) because we learn directly from our experience 'that a body rest or in motion continues for ever in its present state, till put from it by some new cause; and that a body impelled takes as much motion from the impelling body as it acquires itself' (Hume 1975(E), p.53). The former claim is simply false: what we normally experience is that a ball thrown in the air stops elevating (moving) at one point, even if there is nothing which halts it; and that an unsuspended ball starts falling, even if no object exercises any 'impulse' on it. In fact, before Galileo, Descartes and Newton, it was such observations on which the (Aristotelian) theory of motion was based.

[16]For an excellent historical exposition about the relation between Hume and occasionalism see Kail 2008; about the occasionalist tradition more generally see Freddoso 1988.

[17]For questions concerning the knowability of such properties see again Loewer 2007.

[18]Feynman 1965 is still an excellent introduction on which laws have a prominent, fundamental role in physics.

[19]About the distinction concerning the two notions of fundamentality see also Demarest 2017.

[20]In fact, Lewis's own account of laws, a version of the Best System Account, must understand the fundamentality of laws in this latter sense. Since, according to such accounts, laws are theorems in a deductive system, that is to say, they are the consequences of the system's axioms. It seems natural to assume that the axioms of such deductive systems are its most fundamental laws.

[21]Although it is often claimed that these two must be entirely different activities (for instance, by Ellis 2001 and Heil 2017) because Cartesian matter is 'passive', this is not quite right. In Cartesian physics, at least some fundamental laws are *a priori* connected to the properties of matter understood as pure extension. It is true that Descartes refers to the immutability of God as the ultimate metaphysical ground of his conservation laws. But he never says that the existence of matter *as he understands it* would be metaphysically compatible with the falsity of those laws.

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