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LAWS OF NATURE

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Abstract

The role of properties in specifying different views on laws of nature is significant: virtually any position on laws will make some reference to properties, and some of the leading views even reduce laws to properties. This chapter will first outline what laws of nature are typically taken to be and then specify their connection to properties in more detail. We shall see that different conceptions of properties also result in different views of the modal status of laws, such as the question whether laws are metaphysically necessary or contingent. Some conceptions of properties that have an especially intimate connection to laws include natural, essential, and dispositional properties. Finally, there are also important links specifically between properties, natural kinds, and laws of nature that deserve our attention.

1 What are laws of nature?

Properties have an important role in specifying different views on laws of nature: virtually any position on laws will make some reference to properties, and some of the leading views even reduce laws to properties. This chapter will first outline what laws of nature are typically taken to be and then specify their connection to properties in more detail. We then move on to consider three different accounts of properties: natural, essential, and dispositional properties, and we shall see that different conceptions of properties also result in different views of the modal status of laws, such as the question whether laws are metaphysically necessary or contingent. Finally, there are also important links specifically between properties, natural kinds, and laws of nature that deserve our attention.

In scientific language, we continuously speak about laws of nature, but it is not immediately obvious what makes something a *law*. Some typical examples of laws of nature include Newton's laws, Coulomb's law, the ideal gas law (equation), and so on. At the highest level of generality, we could say that laws concern *regularities*, but it's important to see that not all regularities are lawful or 'law-like'. To see this, consider the following classic example:

(1) All gold spheres are less than a mile in diameter.

(2) All uranium spheres are less than a mile in diameter.

In the case of (1), the regularity being expressed seems to be a mere *contingent* fact, whereas (2) could be considered to express or be based on a law of nature. So, what is the difference between genuine laws and mere contingent regularities? A possible starting point is that we can make *predictions* about the future based on laws, but that does not in itself provide a systematic way to distinguish between cases like (1) from cases like (2) because we often make predictions based on (rough) generalisations as well. For instance, the fact that I have had sandwiches for breakfast every day this week might lead one to predict (accurately) that I will have a sandwich for breakfast tomorrow, but this is hardly a law-like regularity, even if I do have sandwiches for breakfast most mornings.

A more promising starting point would be to find some way to connect laws with *necessity*. Indeed, nomological, natural or physical necessity (all of these modal notions have been used synonymously) is generally defined in terms of laws of nature, so the connection between laws and modality is intimate. However, the basic question still remains unanswered: what is it to be a law? Here are some general approaches:

1. Dretske-Tooley-Armstrong (DTA) account based on relations between universals.
2. Mill-Ramsey-Lewis or 'best systems': the Humean approach.
3. Scientific / dispositional essentialism (e.g., Brian Ellis & Caroline Lierse, Alexander Bird, Anjan Chakravartty).
4. A powers or potentiality-based view (e.g., Heather Demarest, Samuel Kimpton-Nye, cf. also Barbara Vetter).
5. Anti-realism (e.g., Bas van Fraassen, Stephen Mumford).

6. Anti-reductionism / primitivism (e.g., Marc Lange, Tim Maudlin, cf. also ontic structural realism as developed by Steven French and James Ladyman).

It will not be possible to do justice to all these views – and their treatment of properties – in this chapter, so I will mainly concentrate on the first three of these general approaches, with some reference to the fourth.[1]

2 All *F*s are *G*

When thinking about the relationship between laws and properties, the Dretske-Tooley-Armstrong (DTA) account is a very natural starting point, given that it is based on the idea that laws express relations between *universal properties*. I will illustrate the account through Dretske's classic paper 'Laws of Nature' (1977; see also Niiniluoto's 1978 response to Dretske). Dretske starts from criticising the thought according to which laws are simply a set of universal generalisations. Formally, we may express this as follows: $\forall x\ (Fx \supset Gx)$. In other words: all *F*s are *G*. We may replace *F* and *G* with predicates like the ones in the following examples:

- All metals conduct electricity.
- All diamonds are hard.
- All electrons attract positively charged particles.

The thought is that if these generalisations are true, then they express laws. So, laws are generalisations from empirical data. We observe that this *F* is *G*, that *F* is *G*, and indeed that all examined *F*s are *G*, which leads to the generalisation expressed above formally with the universal quantifier '∀'. The idea that Dretske questions is that we do not have to postulate a *physical necessity* between *F* and *G* – all we need is the fact that all *F*s just are *G*. Compare: we do not confirm the analytically true statement 'All bachelors are unmarried' by investigating individual cases of the marital status of bachelors. This would of course support the truth of the claim, but not its modal status as necessary. So, the line of thought that this

[1] Sometimes theories of laws of nature (or natural necessity) are broadly classified as Humean or non-Humean, where at least (1), (3), (4) and (6) would count as non-Humean; (5) is somewhat more difficult to classify. For a survey of the non-Humean approaches, see Hildebrand 2020. For a survey of the Humean approaches, see Bhogal 2020.

might be considered to support is that since we *do* examine individual cases of laws in order to confirm them, this suggests that there is no special modal force involved in laws.

However, as should be clear from my naïve example featuring sandwiches, just the fact that all of my breakfasts consist of sandwiches does not make it a *law*. There is a broad consensus according to which laws cannot just be universal generalisations (for a more striking example, recall the gold vs. uranium sphere case). Compare: let us assume that $\forall x\ (Fx \supset Gx)$. If we now substitute '*F*' with some predicate '*K*' that happens to be coextensive with '*F*', we have $\forall x\ (Kx \supset Gx)$. What does this entail? Well, according to Dretske, genuine laws are simply not compatible with these types of substitutions. The example he provides can be reconstructed as follow:

(1) Diamonds have a refractive index of 2.419 (law).
(2) 'To be a diamond' is coextensive with 'is mined in kimberlite (a dark basic rock)'.
(3) By substitution, it would follow that 'things mined in kimberlite have a refractive index of 2.419'.

We now see that the result in (3) cannot be a law since there are plenty of other things besides diamonds that we can mine in kimberlite. Accordingly, replacing the predicate with a coextensive one like in this example may lead to a change in the law status!

It should now be clear that in order for the connection between two predicates to be a genuine law, something more is needed. This is exactly what Dretske proposes. He puts it famously: '*F*-ness ⟶ *G*-ness', where he describes '⟶' to be an extensional relation between the terms '*F*-ness' and '*G*-ness' (which we may understand as referring to *properties*). On this view, laws concern properties like length, mass, charge, spin etc., and more precisely, they express relations between these properties. Dretske considers it an advantage that, on his formulation, we can replace the predicate '*F*' with any term that refers to the *same property*. So, unlike with the earlier issue regarding coextensive predicates, we can safely substitute *F* and *G* with any term as long as they pick up the same property.

Moreover, we can now explain the modal force of laws: the contingent relation between *F* and *G* produces the necessity of the phenomenon captured by the law. This *F must* be a *G*. Why? Because *F*-ness is linked to *G*-ness. One property 'produces' the other one. It's worth noting here that, in Dretske's picture, the modality in question is nomological or physical but not metaphysical necessity. Dretske compares laws of nature to the relationship between the President and the Congress: these relations are not necessary in a strong sense, but they nevertheless have modal strength. This is similar to Armstrong's (1983) view, who talks about *nomic necessitation* as opposed to *metaphysical necessitation* – in other words, the DTA account retains a level of (metaphysical) contingency regarding laws. Dretske concludes with the following famous passage, which nicely summarises the relevant view about the connection between properties and laws:

> I expect to hear charges of Platonism. They would be premature. I have not argued that there are universal properties. I have been concerned to establish something weaker, something conditional in nature: viz., universal properties exist, and there exists a definite relationship between these universal properties, if there are any laws of nature. If one prefers desert landscapes, prefers to keep one's ontology respectably nominalistic, I can and do sympathize. I would merely point out that in such barren terrain there are no laws, nor is there anything that can be dressed up to look like a law. These are inflationary times, and the cost of nominalism has just gone up. (Dretske 1977: 267–268.)

Dretske is of course referring to the debate between Platonism and nominalism (about universal properties in particular).[2] His conclusion is that in order to have laws we need universal properties and the relations between them – and these are not available to the nominalist. We should however acknowledge that one does not need to be a Platonist in order to believe in universal properties, as on certain Aristotelian views universal properties can be regarded as existing only when they are instantiated – this idea is also familiar from

[2] On the universal/particular distinction, see ch. 5, this volume, on Platonic universals, see ch. 11, this volume, and on nominalism more generally, see Part 4 of this volume.

Armstrong's (1989a: 75) famous *principle of instantiation*, which requires that any universal must be instantiated by some particular.[3]

3 Laws of nature and natural properties

The approach to the relationship between laws and properties to be outlined in this section is best known from David Lewis's work, but the 'Humean' approach that he advocated is now very popular. The central thought of this approach is that laws are a part of those true deductive systems which have the *best* combination of strength/simplicity/explanatory power.[4] This view can quite easily accommodate the distinction between the generalisation that all gold spheres are less than a mile in diameter and the law-like nature of all uranium spheres being less than a mile in diameter. The thought here is that the latter fact would follow deductively from the axioms that are constitutive of the best system, but the former fact would not be among these axioms, nor entailed by them. So, the "law" concerning gold spheres does not add any strength or explanatory power to our system, and instead only makes it more complicated. Hence, it should not be included (and so isn't really a law).

The theory has certain advantages, and variations of the Humean approach have been discussed extensively. A central motivation is that we might be able to explain everything based on 'local matters of particular fact', i.e., point-like facts in spacetime. The world is a Humean *mosaic* of such facts. The Humean mosaic may be considered to consist of fundamental, (perfectly) *natural properties*. Accordingly, the mentioned notion of *simplicity* when it comes to best systems can be understood in terms of relative *naturalness*: the more natural the relevant properties are, the simpler the resulting system. The reasoning here is as follows.[5] *Simplicity* is a feature of the relevant theories and the system as a whole, but even when combined with *strength*, there is a risk of triviality. The risk can be illuminated by considering a *maximally strong* and simple system, which just consists of one all-encompassing predicate, '*W*', that describes or applies to the whole universe and captures its

[3] See ch. 12, this volume, for further discussion of Aristotelian views and Tugby 2022 for a comprehensive defence of Platonism.

[4] See Lewis 1983, 1986 for the classic presentation of his system, and, e.g., Loewer 2007, Schrenk 2014, Hicks 2018, Jaag and Loew 2020, and Friend 2022 for some recent discussion. There are also views that combine a non-Humean approach to ontology with a Humean approach to laws, such as Demarest 2017 and Kimpton-Nye 2017.

[5] Thanks to Samuel Kimpton-Nye for helping to spell this out as clearly as possible.

goings-on with a single high-level law. This system may be strong and simple, but it would lack in explanatory power. In order to avoid this type of result, we may introduce the requirement that the predicates in our best system must refer to (perfectly) natural properties, which helps to restrict the system and ensure that we have at least some objective measure for what is ‘best’.

Given this line of thought, it is clearly the notion of *natural* vs. *abundant* properties that does a lot of work in this theory, and natural properties have an especially important role in the account of laws of nature (on sparse/abundant properties, see ch. 4, this volume).[6] There are various approaches to natural properties and one central issue concerns the question of whether naturalness comes in degrees or whether the only genuinely natural properties are the *perfectly* natural properties. Following Schaffer (2004: 94), we can distinguish the following broad qualifications for being a natural or *sparse* property (the notions are often used synonymously):

(1) Similarity: sparse properties ground objective similarities;

(2) Causality: sparse properties carve out causal powers; and

(3) Minimality: sparse properties serve as a minimal ontological base.

Conversely, non-natural or abundant properties could be picked out by any meaningful predicates that we might imagine, such as ‘being my favourite breakfast food’ (i.e., a sandwich!). The three listed criteria for naturalness or sparsity can of course be questioned. Schaffer himself drops (3) and distinguishes the *scientific* vs. *fundamental* conception of sparsity, where the first suggests that sparse properties are those invoked in the ‘scientific’ understanding of the world. However, we might reasonably ask: what counts as ‘scientific’? For instance, are psychological or social properties included?[7] But if one favours the fundamental conception, whereby only fundamental or perfectly natural properties should be included, then one faces some difficult questions about what counts as the *minimal*

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[6] For a recent account developing a ‘package deal’ of laws and properties inspired by the Lewisian best systems account, see Loewer 2021.

[7] In fact, we may ask this question about any of the various types of properties discussed in Parts 8 and 9 of this volume.

ontological base. If a 'gunky' world is possible, i.e., a world where everything is a proper part and there are no simples, and hence no true mereologically fundamental level, then it might appear that *nothing* counts as natural according to (3) and we can't get the account off the ground, as it were.[8] Still, there are many ways to specify naturalness (albeit one can also take it to be a primitive notion, like Lewis himself probably did), and it's clear that this approach provides one popular and promising route to connect laws of nature and properties.

4 Laws of nature and essential properties

Essential properties concern the individual or general natures of entities, and have been historically closely connected to laws of nature, although not always explicitly (such as in Aristotle's work, since the contemporary notion of a 'law of nature' had not yet been invented). The basic connection between essential properties and laws of nature is that laws may be thought to 'flow' from these properties in some manner (see, e.g., Bird 2007, Oderberg 2011, and Kimpton-Nye 2021). However, we should start from the distinction between *individual* vs. *general* essences (cf. Lowe 2008: 35). We may ask: is it essential to an individual x to be of kind K? This would be a question concerning the individual essence of x. But we may further ask: what is it that each member of kind K shares that makes it a member of the kind? This would be a question concerning the *general essence* of the members of K, and the answer could be that they share a given essential property or properties. Every entity will have a general essence in the sense that it is a member of a given ontological category or kind, but it may or may not be essential to the individual that it is a member of that kind. Moreover, not everyone accepts individual essences at all. We can set this complication aside though, since for the purposes of connecting essential properties and laws, it is the general essence that would seem to do the work, as I hope to make clear in what follows.

A key question regarding the understanding of essence is the relationship with the essence of an entity and its essential properties, i.e., whether the essence is something over and above the 'bundle' of the essential properties. David Oderberg calls this the 'unity problem': 'if the essence is a group (set, bundle) of properties, what holds those properties

[8] For an overview of different conceptions of fundamentality, see Tahko 2018.

together?' (Oderberg 2011: 90ff).[9] Now, the connection to laws becomes evident when we consider one possible answer to the unity problem, namely, that a law of nature holds the essential properties together (or that it is a law of nature that they always come together). Analysing this suggestion will also help to illustrate how an account of laws based on essential properties differs from the DTA-style nomic necessitation account considered in section 2.

We can start by assuming that it is part of the essence of electrons, i.e., the general essence of the natural kind *electron*, that they possess unit negative charge. So, electrons have the property of unit negative charge essentially. This fact by itself does not appear to be law-like in the sense that we have been discussing earlier in connection to the DTA account, because there is no relation between the universal properties at hand – we just have the fact that electrons have a certain property essentially. Oderberg summarises the core issue succinctly (building on Bird 2007):

> We might think of the property *being an electron* as a complex property whose parts are, at least, the properties *being an elementary particle* and *carrying unit negative electrical charge*. Call these properties *E* and *U*, and represent the property *being an electron* as [*E*, *U*]. On the necessitation theory, then, there is a higher-order relation of necessitation between [*E*, *U*] and *U*. Such a relation exists, to be sure, but it is nothing other than necessary inclusion. Since, by definition, we already know that *being an electron* consists in part of *carrying unit negative electrical charge*, to assert that it does so in the form of a purported law statement is to add no new fact to the simple fact that electrons exist. In other words, the appeal to law as an explanation of why electrons carry unit negative electrical charge is an illusion. (Oderberg 2011: 91.)

The 'necessitation theory' that Oderberg refers to is the DTA-style account. The upshot for our discussion is that if there is a connection between laws and general essences or essential

[9] See also Dumsday 2010 on 'complex essences', Keinänen and Tahko 2019 on a bundle theoretic approach, and Hommen 2021 more generally on kinds as universals.

properties, it looks unlikely to be of the form where the laws explain features of essence. But could it be the other way around? Indeed, perhaps the most interesting connection to laws when it comes to essential properties is that if the modal force of laws somehow 'flows' directly from essential properties, then laws may appear to be metaphysically necessary rather than just nomologically or physically necessary – that is, laws of nature could not vary across possible worlds.[10] This type of view is most familiar from the framework of scientific or dispositional essentialism, to which we now turn.

5 Laws of nature and dispositional properties

Glass has the *disposition* to break; it's *fragile*. Electrons have the disposition to attract positively charged particles, poison has the disposition to kill, water has the disposition to dissolve salt and so on. The historical background of dispositional properties can be traced to Aristotle's *dunamis*, i.e., *potentiality* or Locke's powers (developed in contemporary metaphysics, e.g., by Barbara Vetter 2015; see also ch. 24 and ch. 28, this volume). *Dispositional properties* are sometimes analysed as *possibilities,* but they might not or don't have to manifest. Alternatively, dispositions are often analysed in terms of *counterfactuals*: '*if* we were to put this salt into some water, it *would* dissolve'. The relevant position that endorses properties with dispositional essences is usually known either as *scientific essentialism* or *dispositional essentialism* (e.g., Ellis and Lierse 1994, Ellis 2001, Bird 2007; the roots of the view are already in Putnam 1975 and Kripke 1980). Views falling under these labels generally share an opposition to the Humean position about *categorical properties* which do not link to any manifestation, i.e., they do not *do* anything (so have no causal powers).

Categorical properties tell us how something is in itself, not how it behaves. On this view about properties, a property's 'essence', if it can be thought to have one at all, is something non-dispositional and intrinsic, a 'quiddity' (as labelled by Armstrong 1989b).[11] Resisting this line, the dispositional or scientific essentialists hold that the essence of object *O*

[10] But see Tahko 2015b, where the question of contingent laws in an essentialist framework is examined, and Oderberg 2018 and Hireche et al. 2021 for critical discussion.

[11] For some good discussion of intrinsic properties, see Sider 1996 and Whittle 2006, and on quidditism, see Hildebrand 2016; Smith 2016; Wang 2016.

consists in its entirety of the causal roles of *O*, and there is generally a necessary connection between the behaviour of a property and its causal or dispositional profile.

The view regarding laws that emerges from all this is that we can explain all law-like behaviour strictly in terms of the dispositional essences of properties. Electrons essentially have a unit negative charge, and it's essential to the property of unit negative charge that it attracts positively charged particles. The upshot is that any relevant laws, such as those governing electrostatic interaction (van der Waals interaction), i.e., the attractive or repulsive interaction between objects having electric charges, can ultimately be explained in terms of the relevant dispositional essence of charge (possibly together with any other relevant dispositional essences).[12] Moreover, if essences are understood as being metaphysically necessary to these dispositional properties, then we can trust that the relevant laws hold in all possible worlds, rendering them metaphysically necessary. The picture is very neat and has enjoyed wide support and various modifications.[13] However, there are well-known problems with this approach as well. These concern laws that are not easily understood in terms of dispositional properties, such as conservation laws and symmetry principles (for discussion, see Bigelow, Ellis, and Lierse 1992; Bird 2007: 211–214; Vetter 2012; Jaag 2014).

6 Laws, kinds, and properties

I will conclude with a brief discussion of the connection between laws of nature, natural kinds, and the properties that members of natural kinds share. Natural kinds themselves may be conceived in many ways, e.g., as bundles of properties, substantial universals, *sui generis* entities, and so on.[14] This in itself may have implications regarding their connection to laws of nature, and the relevant modal status of the laws. For instance, one may regard laws to be metaphysically necessary because they feature natural kinds, as E. J. Lowe (2006) has argued. We need to understand the relationship between natural kinds and the properties that their members have in order to clarify the role of laws. More specifically, we can distinguish three main questions about the relationship between kinds and properties (following Tahko 2022):

[12] It should be noted that, for some (in particular, Mumford 1998), this suggests that there really are no laws because all the work is done by the relevant dispositional essences.

[13] For some recent developments, see, e.g., Ingthorsson 2013; Yates 2015; McKitrick 2018; Kistler 2020; Groff 2021; Kimpton-Nye 2021.

[14] See Tahko 2015a, 2022, forthcoming, and ch. 29, this volume.

(1) *What* are natural kinds, that is, what sort of entity (e.g., universals, bundles of properties…)?

(2) *Why* are properties systematically clustered together in members of natural kinds?

(3) *How* are the clustered properties unified in instances of kinds?

One possible line of reasoning to answer (1) – (3) (modelled after Lowe 2006) would be to say that:

(1*) Natural kinds are substantial (Aristotelian) universals;

(2*) which are characterized by attributes (property universals) and instantiated by individual substances (instances of kinds);

(3*) and the clustering of the properties is governed (at least partially) by laws of nature featuring the relevant kind universals.

From (1)-(3) we see that the connection between laws, properties, and kinds will, unsurprisingly, depend on one's views regarding the underlying ontology. The view outlined here, roughly in the spirit of Lowe's proposal, is also close to my own view: laws may play a role in *unifying* the properties that members of natural kinds have.

Interestingly, this brings us back to the problem of unity, which we briefly examined in section 4. We might compare this to Oderberg's account, whereby the properties that 'flow' from the essence of a particular object belonging to a given kind are *caused by* and *originate* in the *form* of that kind (Oderberg 2011: 99–103). But, as we saw earlier, we need to ask the further question of *how* the relevant properties are unified. We have no obvious evidence that there are any *causal* connections between the essential properties of fundamental natural kinds such as, say, *electron* – or between the kind itself and its properties.

In fact, fundamental kinds are an especially problematic case and some (e.g., Chakravartty 2007: 171) have suggested that at least fundamental natural kinds unify their properties as a matter of *brute fact*. On this view, fundamental natural kinds, such as (supposedly) electrons, have their core properties (mass, charge, spin) as a matter of brute fact. However, it is problematic to conclude that there is no further explanation to the unity problem just because some cases of unification look to *us* like brute facts. It is another matter whether or not we are ever in a position to *know* how unification works in such cases.

These subtle questions regarding the interplay between properties, natural kinds, and laws of nature are clearly at the core of many approaches to laws and properties, and we can expect the debate to continue.[15]

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[15] Thanks to Samuel Kimpton-Nye for comments on an earlier draft of this chapter.

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