Laws of Nature and their Limitations

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Some Distinctions and Questions

The word "law" has numerous connotations which need to be clarified before understanding which sense is intended by the phrase "law of nature". A law is some principle or rule which governs some event or behaviour, but the notion of "governing" could be explanatory, prescriptive, descriptive or definitional.

- A law is *explanatory* to the extent that it proposes some account of *why* some event or behaviour happens. For instance, candles cannot be lit in a vacuum because fire requires oxygen and there is no oxygen in a vacuum. Such laws often use the word "because" to link the phenomenon to be explained to other phenomena and/or principles which are taken to be already granted.
- A law is *prescriptive* to the extent that it states what *has to* or what *ought to* happen. Such laws define boundaries or restrictions on behaviour. For instance, laws of jurisprudence prescribe how people should act within society. The laws of any game (more commonly called "rules" because of their limited scope) restrict the behaviour allowed within the context of that game. The law of non-contradiction, viewed as a law of thought, prescribes a limit on what counts as rational thinking; viewed as a law of formal logic, it places a syntactic restriction on what can be asserted or deduced within the formal system.
- A law is *descriptive* to the extent that it provides merely a description of what occurs, with no claim about what ought to happen and no account of why it happens. For instance, a law which claimed that all ravens were black.
- A law is *definitional* to the extent that it specifies a relationship of logical necessity between a term and the behaviour it defines. Such a relationship can rarely be called a genuine law, yet it can happen that some claim given the status of law may, on closer inspection, be merely a definition. For instance, it could be the case that Newton's second law of motion, normally expressed in the equation F=ma, is only a definition of force in terms of mass and acceleration. If, however, the relationship between force, mass and acceleration is established *after* they have all been independently well-defined, then the relationship is descriptive rather than definitional.

Laws of nature (sometimes called nomic laws) are those which govern naturally occurring phenomena such as motion, chemical reactions, quasars, fluid dynamics and genetics — in short, the types of phenomena studied by empirical science. We shall be asking whether there *are* any such laws and if so, what form they take? Do they explain, prescribe or simply describe the phenomena? It may be that there are *no* patterns or regularities in nature, but only our psychological disposition to impose such patterns on the world. If this were the case then there can be no laws of nature since a law of nature implies that some generalisation can be made about some class of events. The converse is not required — there may be true generalisations about natural events and yet those generalisations may be accidental and the events not governed by any law[1]. So a further avenue of our inquiry will be into how accidental generalisations can be distinguished from laws of nature.

We shall also consider the extent to which such laws can be known, and the relationship between statements of laws and the laws they purport to express. The epistemological issue is quite separate from the ontological one, and it is important to avoid "the tendency to conflate laws with the verbal or symbolic expression of these laws" (Dretske p. 255).

Several further distinctions need to be made between types of laws of nature before any substantial discussion —

- Some laws claim that there can be no guarantee of a specified phenomena occurring, but only a certain level of *probability* that it will be the case. The paradigmatic example is of radioactive half-life — that a body of (say) plutonium will decay to half its mass every so-many years. Such a law claims that each atom has a certain probability of decaying in a given time, but does not specify any way of determining which atoms will decay when. In fact it may be explicit in the statement of the law that the time before any particular atom will decay is inherently indeterminable. Nevertheless, the statistical outcome of repeated probabilistic events at the atomic level is that a large enough body of plutonium actually does decay at the specified rate.

  In contrast to these probabilistic laws, the majority of statements of laws of nature are *deterministic*. That is, they assert that, given some specified conditions, a certain phenomenon will occur 100% of the time. The basic form of such laws is a claim that all instances of some phenomena are also instances of some other phenomena — all natural situations which satisfy some predicate (say F) also satisfy another predicate (G). Many deterministic laws are not normally expressed in this way, but most *can be* so expressed. For example the Law of Conservation of Energy, that the total energy of an isolated system remains constant, could be expressed as "All natural systems which are isolated are situations in which the total energy is invariant over time." In this form, the first predicate (isolation) specifies the pre-conditions under which the law applies, and the second predicate (invariance of total energy) specifies some restriction on the phenomena which may occur given those pre-conditions. Most of the discussion which follows will focus on this formulation.

- It is well-accepted that some laws of nature depend on others. Such laws are called *derived*, whereas the more basic or primitive laws are called *fundamental* (or "ultimate" (Ramsey p. 130)) although the exact distinction is open to question. According to Nagel, fundamental laws are those which contain no individual names and whose predicates are all purely qualitative (Nagel p. 57); derived laws are those which are logical consequences of some set of fundamental laws. Pargetter allows a larger set of fundamental laws by including all laws which are logically entailed by other fundamental laws. For him, derived laws are those universal generalisations which are entailed by other laws *conjoined with accidental facts* (Pargetter p. 345). For instance, a law about the attraction between large bodies (i.e. gravity) may be fundamental, while a law about the elliptical orbits of planets in our solar system is derived from that fundamental law plus details of the masses and spatial configuration of planets.[2]

- Many laws of nature are *causal*, i.e. they assert that some phenomenon is the cause of some other phenomenon. There is a close association between causation and laws, but not all laws need to be causal. For instance, Newton's second law of motion claims a relationship of interdependence between force, mass and acceleration, but does not claim that the force is caused by the other two factors. Laws like this which co-associate two or more qualities or quantities are called *laws of association*[3] (Cartwright p. 21). Even laws which refer to a temporal sequence of events need not be causal, as Nagel points out in his discussion of "developmental" or "historical" laws (Nagel p. 76).

Three Accounts of Laws of Nature

There are numerous philosophical approaches dealing with what laws of nature are and how they work. In this essay I shall cover three broad approaches — that there are in fact no laws governing nature; that laws are certain types of generalisations based on regularities in nature; and that laws are relations between universals. In each case, there is a clear central idea but more than one account of the details. I am not suggesting that the three categories are the only possibilities nor that the accounts I describe within those categories are exhaustive.

No Laws

Although it is not a commonly held view, it could be that all true generalisations about the world are purely co-incidental and not governed by any law. Regularities simply occur, with no further reason.

One author who espouses such a view is Bas van Fraasen. He calls his anti-realist position "constructive empiricism" and claims that the aim of science is not to establish what is true, but only what is true with respect to observable phenomena (van Fraasen pp. 192f). Following a semantic view of theories, he focuses on models rather than linguistic or axiomatic formulations. Laws play a role in this account, but only as laws of models (e.g. a model's basic principles and equations), not of reality.

The traditional argument against a "no laws" view claims that there must be a reason for the pervasive and stable regularities in nature. If there were no laws, what grounds would there be for believing that regularities will persist? Without laws there can be "no basis for rational expectation of the future" (van Fraasen p. 19, but see his rebuttal of this on p. 21).

A more radical view would be that there are no *bona fide generalisations* in the world but that the supposed regularities of nature result from our psychological disposition to project patterns onto our observational data. As Cartwright points out "Things are made to look the same only when we fail to examine them too closely" (Cartwright p. 19). That is, what appears to us to be regularities would not appear so if we looked at the fine details. Although Cartwright does not adhere to such a picture, she concedes that it is as plausible as the alternative.

Simon Blackburn is one who does hold such a projectivist picture. "We *project* an attitude or habit or other commitment which is not descriptive onto the world, when we speak and think as though there was a property of things which our sayings describe" (Blackburn p. 171). He proposes a quasi-realist framework to explain why our discourse inevitably makes what appear to be Realist commitments and thus supports a Humean view that causality (and by extension, laws) is a phenomenon of cognition and discourse rather than of nature (Blackburn p. 211).

Laws as Regularities

If we grant that there *are* genuine regularities in the world, what could the relationship be between them and laws of nature? According to the Regularity Theory popular in the 1940's and 1950's, the two should be thought of as identical. More precisely —

> *p* is a *statement* of a law of nature if and only iff:
> (i) *p* is universally quantified
> (ii) *p* is omnitemporally and omnispatially true
> (iii) *p* is contingent
> (iv) *p* contains only non-local empirical predicates, apart from logical connectives and quantifiers (Molnar, quoted in Armstrong 1983 p. 12)

This definition refers to a *statement* of law rather than directly to a law. A law is the regularity itself which has been expressed by a statement meeting the four requirements. This allows the possibility of a single law having numerous legitimate statements. That each of these four requirements must be met in order for a phenomena to count as a law is reasonably well accepted. The first requirement states that a law must be universal in scope rather than applying to some limited subset of relevant circumstances. Perhaps we need to be even stricter than this syntactic restriction and ensure that the set of examined cases do not exhaust the scope of predication of the law, otherwise the law could not be used predictively (Nagel p. 63). The second requires that a law be true, always and everywhere. The third restricts the statement to laws of nature by precluding the regularities of logic and mathematics. The fourth ensures that the features which play a role in the law are open to factual confirmation via scientific investigation and that they do not simply apply to a few isolated instances.

However, it is clear that these requirements are not enough. They allow too many merely accidental regularities to count as laws. For instance, "All pieces of gold are less than one million tons" meets the four requirements of a law, even though a larger piece of gold seems to be only an unrealised physical possibility, not a nomic impossibility. In contrast, "All pieces of uranium are less than one million tons" *is* a law of nature since any amount of uranium larger than critical mass will explode. But Molnar's definition is unable to recognise the different status of these two examples.

Phenomena with only single instances can also be stated in such a way as to meet the four requirements. For instance, no-one would accept that "my alarm clock is red" is a law of nature. But I could construct a lengthy non-local empirical predicate which uniquely picked out my alarm clock — $A(x) =_{def}$ "x has such-and-such physical components, arranged in such-and-such a configuration, with a crack of such-and-such dimensions, etc" — and then assert the "law" "All objects satisfying A(x) are red". Even vacuous regularities such as "All pieces of gold larger than one million tons are shaped like cigars" count as laws according to Molnar's definition. Furthermore, the definition precludes the possibility of probabilistic laws, since in such cases it is not true that *all* relevant instances display the same regular behaviour.

The simple version of Regularity Theory can be augmented to address these shortcomings, but even the more sophisticated versions fail to fulfil our intuitions about laws. It is no good, for instance, to add that generalisations are only laws if they are used predictively (nor any other condition which involves human cognition), for that would violate our intuitions that there are laws as yet unknown to us (Armstrong 1983 pp. 61ff).

Ramsey suggests that if we formalised our knowledge as a deductive system, then the axioms of that system would be the fundamental laws of nature (Ramsey p. 131). This changes the emphasis from individual laws to a system of laws and presupposes that an internally consistent deductive system could be constructed with sufficient strength to account for all relevant phenomena. Lewis allows that there could be more than one such deductive system and even when ranked according to their simplicity, there may be more than one "best" system. His extension to Ramsey's view is that "a contingent generalization is a *law of nature* if and only if it appears as a theorem (or axiom) in each of the true deductive systems that achieves a best combination of simplicity and strength" (Lewis p. 73).

The advantage of this axiomatic/deductive view is that it gives an extra criteria by which to distinguish laws from other generalisations. To be a law, a generalisation must not only be true, but also fit together with other generalisations in one of the best possible systems. It also highlights the fact that our statements of laws are only tentative and may be superceded if we later construct a simpler and/or stronger system.

However, given the vagueness of the terms simplicity and strength (which Lewis admits on p. 74), it is hard to see how this view will help solve disputes about whether a given generalisation is a law. If it is unclear whether something is a law, will it be any clearer which deductive system "achieves a best combination of simplicity and strength"? Furthermore, there could always be more than one equally consistent, strong, simple and true system, each logically incompatible with the others. Do we want to accept in such cases that a theorem of one system cannot be considered a law unless it is also a theorem of all the other systems? Looking for simplicity and strength may be a good strategy for science, but not a robust principle for the metaphysical analysis of laws (c.f. Armstrong 1983 p. 73).

Regularity Theorists only nominally believe in laws. For them, laws do not have any separate existence but are reducible to certain generalisations about naturally occurring phenomena. One of the difficulties with any Nominalist view of laws such as Regularity Theories is that if there is nothing governing the regularities in nature then the predictive success of science looks like a complete miracle. I shall not debate the strength of this so-called "miracle (or ultimate) argument" (Carrier 1991 and 1993), but will turn now to a Realist account of laws.

Laws as Relations between Universals

If "It is a law that Fs are Gs" does not mean merely the regularity "All Fs are Gs", then what does it mean? A Realist will conceive of laws "as *the reason which accounts for* uniformity in nature, not the mere uniformity or regularity itself" (van Fraasen p. 22). In line with this observation, Armstrong, Tooley and Dretske have each independently proposed that a law is a relationship between universals which necessitates a relationship between instances of those universals.

Their reasoning is as follows. Firstly, we are motivated by the shortcomings of Regularity Theory to think that "It is a law that Fs are Gs" requires that it be *necessary* that an F is a G. But by this we do not mean simply that in each instance, Fa necessitates Ga — a law is not merely a collection of individual necessitations. Rather, we need to suppose that there is something about all Fs which make them F, something about all Gs which make them G, and then claim that being an F necessitates being a G. These are clearly Realist ontological suppositions since they require the existence of universal properties (F and G) and a relation of necessitation between those properties. (Armstrong 1983 p. 78, 1997 pp. 223ff)

It is as a consequence of the universal relation "F-ness necessitates G-ness" that each instance of an F must also be a G. But note that the converse does not hold — even if all Fs were Gs, it need not be the case that F-ness necessitated G-ness (Dretske p. 253). This conception of laws thus avoids one of the main problems with Regularity Theories, namely the difficulty with distinguishing between accidental generalisations and laws. Even with this approach it is still a difficult task in practice to decide whether a particular generalisation is a law or just accidental (although Tooley describes how this might be done on pp. 687ff), but at least there is a clear conceptual difference between the two.

An advantage of this way of thinking about laws is that it satisfies our intuitions about counterfactuals in a way that non-lawlike generalisations do not. A generalisation of the form "All Fs are Gs" could be written as the lengthy conjunction (Fa&Ga)&(Fb&Gb)&... together with an extra claim that this conjunction covers all the Fs. How would we then analyse the counterfactual claim that "If some z which is neither F nor G were in fact F, then it would also be G"? We can easily suppose z were F by simply adding Fz to the conjunction, but there seems to be nothing forcing us to add Gz as well. However, if "All Fs are Gs" were a law rather than a mere generalisation, then we must expect that adding Fz does somehow necessitate adding Gz as well. A Regularity Theory which maintains that the generalisation is all there is to a law has difficulty meeting this intuition. On the other hand, if "All Fs are Gs" is a law in the sense that the universal F necessitates the universal G, then any counterfactual supposition about an instance Fz will immediately entail Gz as well and hence the intuition about counterfactuals is satisfied. (Armstrong 1997 pp. 259ff, but see also Dretske pp. 255f and Nagel pp. 51f)

Limitations

Given the three approaches described above, I want to consider several ways in which laws of nature may be limited. There are many questions of relevance, such as — Should we expect laws of nature to be complete and comprehensive? Do laws of nature cover all that can happen? Is there reason to doubt even the best possible statements of laws? Do laws admit to exceptions? Are there some laws which we can never, in principle, state? But I shall concentrate on just three issues, namely, the extent to which laws can be seen as explanations, the fallibility of our knowledge of laws, and the extent to which laws must be exceptionless.

Limitations on Explanation

In what way can it be said that laws of nature explain rather than simply describe the phenomena to which they refer? Under a Regularity Theory, laws may describe regularities in nature but cannot provide any account of why the phenomena occur regularly. If a law is simply a statement of a certain type of generalisation then it cannot offer any explanation of that generalisation (Dretske p. 262).

The Armstrong-Tooley-Dretske view gives a better account of explanation. In answer to a question like "Why is this F a G?" they can reply "Because there is a law that F-ness necessitates G-ness and given such a law, every F must be a G" (c. f. Dretske pp. 264, 267). This relationship of necessitation is itself a universal, but it is primitive (Armstrong 1983 p. 88). Armstrong first thought that the universal relation of necessitation was the same sort of thing as singular causation (1983 p. 97f), but later realised (perhaps in response to problems raised in Carroll pp. 162–174) that singular causation was merely one instance of the necessitation relation (1997 p. 227).

This still leaves open the question of why F-ness should necessitate G-ness and one wonders whether the move from relations between particulars to relations between universals has actually provided any explanatory gain. The law explains why things happen as they do, but what explains the law? It is inevitable that explanations stop somewhere and for Armstrong it is nomic necessitation which is primitive and irreducible.

A related issue is the exact sense of the word “necessity” when applied to laws of nature. It is clear that it does not mean *logically* necessary, for the denial of a law of nature is rarely self-contradictory (Nagel p. 53). To the extent that a law is logically necessary, it is probably just definitional. One could say that something is *physically* necessary exactly when it is true in all possible worlds with the same laws as the actual world (Carroll p. 18n) but since this definition relies on the concept of laws, it is of no use in explaining the necessity of those laws. We need to give some explanation of physical necessity without involving circularity. The Armstrong-Tooley-Dretske view holds that a law is a *contingent necessity* (Tooley p. 673, Armstrong 1983 pp. 85, 158–173). That is, it could have been that the relation between universals F and G was not the case, but given that it is the case, it necessitates the relationship between instances of Fs and Gs.

A Nominalist may respond to this that just naming something as “necessitation between universals” does not tell us much about how that necessitation works. What warrants a belief in entities beyond the observed regularities? If we were to live in a world in which regularities just happened without being governed by universal necessitation, things would look exactly as they do now. “Simplicity favours supposing that the laws are the regularities, rather than positing hypothetical back stage apparatus” (Braddon-Mitchell).

Limitations on our Knowledge of Laws

According to Nancy Cartwright, *fundamental* laws apply not to the real world but to a model, that is, to a set of features and relationships abstracted from the real world. Because models are inherently idealised, laws which account perfectly for phenomena in the model world cannot predict events in the real world accurately. Fundamental laws may do a good job of explaining, but are not accurate (Cartwright pp. 3, 55). Their explanatory power comes from the simplification of assumptions on which the model is founded, in particular the simplification by which certain facts and relationships are treated in isolation from others. On the other hand, *phenomenological* laws describe what actually happens, but have no explanatory power (Cartwright pp. 100–127). The recognition of these phenomenological laws distinguishes Cartwright’s view from van Fraasen’s, for van Fraasen would have it that there are *no* laws apart from those applying to models.

If this distinction between fundamental and phenomenological laws is correct, it raises difficult questions about the relationship between the two. However, although Cartwright does not seem to be aware of it, this distinction applies not so much to laws as to statements of laws. The distinction highlights not so much a limitation on the comprehensiveness and accuracy of the actual laws of nature as a limitation on our knowledge of those laws. Any statement of law may be wrong in that it does not correspond to the actual law it seeks to express. Putative laws may not account for all the known data and may be contradicted by future observations. Furthermore, they may be consistent with all data, past and future, and yet not provide the correct explanation of that data. This is always a possibility given the inevitable finiteness of evidence from which statements of law are inferred. There will be numerous mutually exclusive laws (in fact an infinite number of them) which account equally well for any finite set of data. The problems with induction (taking a generalisation which describes the relationships within some finite set of data and applying it to situation outside that set) and abduction (an inference from the knowledge that H would explain E to the conclusion that it *was* H which brought about E) are well known (see for example Chalmers Ch 2, Carnap Ch 2).

The frailty of our knowledge of laws is evidenced both by the history of "laws" which are no longer accepted as true, and the inconsistencies between laws which are still accepted. For instance, the incompatibility of relativity with quantum physics indicates that at least one of those bodies of laws is incorrect. "It is perfectly possible, epistemically possible, that we do not know a single law of nature" (Armstrong 1983 p. 6).

Exceptions to Laws

Given a Regularity account, laws are, by definition, exceptionless — "It is a law that Fs are Gs if and only if all Fs are Gs" (Armstrong 1983 p. 13). Nevertheless, there are various reasons for proposing that laws of nature need not be exceptionless.

One way that exceptions could be allowed in a Regularity Theory is to extend the Ramsey-Lewis "best combination" criterion. Whereas Lewis defines a law in terms of "the true deductive systems that achieves a best combination of simplicity and strength", David Braddon-Mitchell changes the criterion of "truth" from being essential to being one of the ingredients of the trade-off. This would allow a generalisation with exceptions to be a law provided that the decrease in accuracy made the deductive system stronger and simpler. Such "lossy laws" are still compatible with a view that laws are just *pervasive* regularities, even though they are not exceptionless.

Another approach, motivated by a desire to allow divine intervention without the need to define miracles as violations of the laws of nature, is taken by Robert Larmer[4]. His understanding is that "the laws of nature, inasmuch as they are merely conditionals, cannot, by themselves, explain the actual occurrence of an event" (Larmer 1985 p. 228). It is not that a set of laws $\{L_1, L_2, \ldots L_m\}$ on their own can logically necessitate some event E, but only when those laws are combined with a set of initial conditions $\{C_1, C_2, \ldots C_n\}$. If the set of initial conditions were satisfied, then and only then can the laws be used to predict the occurrence of E. From such a perspective, Larmer claims that God could affect the occurrence of E, not by violating any of the set of laws, but by altering the state of affairs, perhaps by creating a new object or by destroying some existing object. As a result of such changes, different laws will apply (or the same laws may apply differently). He argues that such acts of God are analogous to acts by which humans can affect events. "One does not, for example, violate, suspend, or even produce an exception to, the laws of motion if one tosses an extra billiard ball into a group of billiard balls in motion on a billiard table" (Larmer 1985 p. 229).

There seems to me to be two mistakes in this analysis, both reflecting a conception of laws applying in isolation from each other rather than in a complex and interconnected system. Firstly, Larmer's billiard example ignores the fact that humans are *inside* the natural system and their actions, just as much as the billiard balls, are governed by the laws of nature. That is why their action of throwing an extra ball onto the table cannot be seen as violating the laws of motion. God's intervention is essentially different from humans' because his is imposed on the system from *outside*.

Secondly, the distinction between the set of initial conditions and the set of laws obscures the dependence of C_1, C_2, ... and C_n on previous applications of laws. Not only do initial conditions precede (and maybe prompt) the future effects of laws, but they are also the result of law-governed activity. The system of nature is a network of interacting laws and their effects. If some C_i is altered by God destroying some matter, then whatever law would have given rise to that condition has been violated. Similarly, if some C_i is altered by God's creation of matter, it will have no legal pedigree; it will have violated the consistency of the law-governed network. If God creates a piece of matter at location x, then whatever would otherwise have been at that location must be displaced (or destroyed), in which case, at the very least, the law which would have caused the displaced matter to be at x has been violated.

In summary, what differentiates God's action in the world from ours is that his intervention is not governed by the laws of nature and any action of his which alters a state of affairs violates those laws which would have given rise to the state of affairs had God not intervened.

This conclusion, however, does not deny the possibility of God's intervention. Laws of nature are, after all, only laws *of nature* and they do not apply to the non-natural. By analogy, the laws of Australia only apply within the confines of Australia and even there they may not be restrictive to foreign diplomates. Within a law-governed system such as nature, events occur as described by those laws. In much the same way, variables change values in a computer simulation as described by the rules of the governing program. But in a sense, God has diplomatic immunity with respect to the laws of nature.

From a perspective within a computer simulation[5] (i.e. with access only to the variables and their changing states) the programmed rules cannot be known directly. Any attempt to account for the simulation's behaviour from this perspective would, at best, yield rules *describing* the state changes. From the programmer's perspective outside the simulation, however, the program rules *prescribe* the simulation's behaviour. Furthermore, these rules, while prescriptive for the simulation, are not prescriptive for the programmer. It is possible for a computer operator to interfere with a computer simulation by changing either variable values or the programmed rules. Either type of intervention constitutes a violation of the original rules of the simulation. I take it that God's intervention in the world operates in the same way — he is not bound by laws of nature, but any act which overrides the normal course of nature is a violation of those laws.

It is clear from this discussion that I disagree with Hume's assertion that violations of the laws of nature are impossible (Hume pp. 109ff). It seems to me that such an assertion only applies to agents within the law-governed system. Hume gives a strong argument for why such agents should discount any evidence for particular miracles, but fails to consider the perspective from outside the system.

A more promising approach than Larmer's denial that miracles violate laws is Lowe's reconception of laws as normative.

> According to the normative account of laws, a statement of natural law ... characteristically implies that *normal* or *typical* individuals or exemplars of some recognisable natural kind possess a certain dispositional property, that is, are disposed to behave or appear in a certain way (usually in certain specifiable conditions). (Lowe p. 273)

Lowe considers a claim such as "Ravens are black" not to be violated by certain types of exceptions (such as an albino raven). If "Ravens are black" were a law it would not require *all* ravens to be black, but only the weaker claim that "normal exemplars of the raven species are naturally disposed to grow black plumage" (Lowe p. 274). Provided that there are independent reasons for supposing albino ravens to be *abnormal* (e.g. some explanation in terms of genetic defect), they pose no threat to the law. What would threaten the law would be the discovery of a sub-species of raven which was non-black. Lowe is not claiming that normative laws are only approximations: they are accurate generalisations about the class of situations specified by their pre-conditions (e.g. the raven species as a whole) even though they may not apply to every individual instance of those pre-conditions.

This approach has the advantage that it allows for the effects of a law to be prevented by some other event or law. In contrast, the traditional approach appends an exclusion clause to each statement of law (what Cartwright calls a “*ceteris paribus* law”, c.f. Armstrong’s “oaken law” (Armstrong 1983 pp. 147–150), later renamed “defeasible law” (Armstrong 1997 p. 231)) which, in effect, apologises for the law’s lack of generality. Such exclusion clauses are never spelt out in full because they would be too long, in fact potentially infinite. A normative conception already allows for a network of interacting and perhaps competing laws, without needing to make that allowance explicit in every statement of law.

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Endnotes

[1] C.f. "Laws imply universal truths, but universal truths do not imply laws" (Dretske p. 253).
[2] Nagel's use of this same Keplerian example indicates that his "derived laws" also depend on accidental facts. If he made this implicit involvement of accidental facts explicit, Nagel's definition would probably end up identical with Pargetter's. On the other hand, Ramsey explicitly wants derivative laws *not* to involve accidental facts — laws which do, he terms "laws in a loose sense" (Ramsey p. 130).
[3] The most common form of laws of association (perhaps the most common form of all useful laws in science) is that of functional dependence in which certain quantities are related to others via some mathematic function. I have not included the problems with these types of laws in this essay, but there is a good discussion in Armstrong 1997 pp. 242–248.
[4] My discussion is based purely on Larmer 1985, although readers may also be interested in MacGill 1992 and Larmer 1992.
[5] I think this analogy comes from Donald MacKay, perhaps in *The Clockwork Image*, though I have been unable to find the reference. The same point could be made by discussing the way the Sphere violated the laws of Flatland (Abbott pp. 77ff).