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Laws (Scientific)

Introduction

Laws of nature are central to science, but what *is* a law of nature? It is quite easy to give some examples: Coulomb's Law of electrostatic attraction, Snell's law of refraction, the Schrödinger equation for the evolution of a quantum-mechanical system. But what do these things have in common in virtue of which they get to count as laws of nature? What is it to *be* a law of nature? For short, and from now on: *what is a law of nature?* While this is primarily a philosophical question, it should be no less interesting to scientists and students of science than, say, the foundations of quantum mechanics. Of course, there are many scientists to whom the latter is of no interest: the "shut up and calculate" types. But if one is not content with merely using science as a tool and would like to go further and investigate what science says the world is really *like*, then one should find something of interest in our philosophical question: "what is a law of nature?".

Simple Regularity View

To get a sense of why the question "what is a law of nature?" is puzzling, it will help to consider a very simple answer first. According to the Simple Regularity View, laws of nature are true generalizations, roughly of the form "all Fs are Gs", i.e., *regularities* in nature. A generalization of the form "all Fs are Gs" is *true* if, and only if, there are no Fs that are not Gs.

The following are thus some candidates for lawhood:

LIST 1

- All swans are white
- All marsupials have a pouch
- All philosophers like coffee

There are black swans in Australia, the short-tailed opossum is a marsupial that does not have a pouch and (apparently) some philosophers do not like coffee. So, none of the examples in LIST 1 are laws according to the Simple Regularity View because they have exceptions and hence are not true.

Now consider:

LIST 2

- Everything travels at or below light-speed
- All massive objects exert a gravitational force on all other massive objects
- All uranium spheres are less than 1 mile in diameter

The examples in LIST 2 are true generalizations; they hold at all times and places in the universe without exception. So, according to the Simple Regularity View, all the examples on LIST 2 are laws of nature.

So far so good for Simple Regularity View, it provides a simple answer to our question "what is a law of nature?", namely, to be a law is to be a true generalization, and it seems to appropriately classify our examples; plausibly, it is not a law that all philosophers like coffee but it is a law that everything travels at or below light-speed.

But now consider the following: "all gold spheres are less than 1 mile in diameter". It is certainly the case that no gold sphere greater than 1 mile in diameter has ever been discovered. Let's assume, then, that there really are no gold spheres greater than 1 mile in diameter (there never have been and never will be). That is to say, "all gold spheres are less than 1 mile in diameter" holds at all times and places throughout the universe, it is a *true generalization*. According to the Simple Regularity View it is then a *law of nature* that all gold spheres are less than 1 mile in dimeter.

While we may be happy to admit that it is a law that all *uranium* spheres are less than 1 mile in diameter, we probably do not want to say that it is a law that all *gold* spheres are less than 1 mile in diameter. The former has to do with the fact that uranium is an unstable *radioactive* element, whereas the latter seems like a mere accident.

The Simple Regularity View ultimately fails as an account of laws because it is unable to distinguish accidentally true generalizations from lawful ones. There must be more to being a law of nature than simply being a true generalization, but what more is needed?

Sophisticated Regularity View

According to a more sophisticated version of the Simple Regularity View, laws are true generalizations, but not just any true generalizations count as laws. Rather, laws are those true generalizations that make up a particularly efficient systematic description of the entire universe. Let's explore this idea in a little more detail.

Anyone can begin to describe the universe by just listing things that she knows: grass is green, the Eiffel Tower is in Paris, electrons are negatively charged, etc. If we knew absolutely everything there is to know about the entire universe, past, present and future, we could continue this list on until we had described the universe in its entirety.

There are more and less efficient ways of describing the universe. Including "grass is green" in our descriptive list is more efficient than specifying each blade of grass by some coordinate system and saying of it that it is green, but is perhaps less efficient than saying that all chlorophyll containing plants are green. The most efficient description of the universe is the one that is the *strongest*, by which we mean that it is highly informative because it logically implies the most information about matters of fact (such as that grass is green, electrons are negatively charged, etc.) in the *simplest* manner possible, i.e., by including as few basic, that is non-derived, statements possible.

Strength and *simplicity* are what we might call *virtues* of a description of the universe because a description is better the more informative it is and the simpler it is. But these virtues *compete*. The stronger an overall description of the universe is, the less simple that description will be because it will contain more basic statements. And the simpler a description is, i.e., the fewer basic statements it contains, the weaker it will be because it will have fewer resources to directly say, or logically entail, true things about the universe.

The best description of the universe will be the one that strikes the optimal balance between strength and simplicity. According to the Sophisticated Regularity View, laws of nature are those true generalizations that either are, or are logically entailed by, the basic statements in the *best* description of the universe, i.e., the one that strikes the optimal balance between strength and simplicity. There is no pressure on the best description to entail *all* truths about the universe, because a great many truths are of little to no interest to scientists, such as: my living room walls are green, post boxes are red, etc., and we wouldn't want to count these as laws anyway. Truths about the universe that are not entailed by the best description will not count as laws of nature.

The idea, then, is that while *all gold spheres are less than 1 mile in dimeter* may be true, it won't be included as, or entailed by, any basic statements of the best description of the universe, i.e., the one that strikes the optimal trade-off between strength and simplicity. The generalization *all uranium spheres are less than 1 mile in dimeter*, by contrast, will be entailed by some basic statement, perhaps about quantum mechanics, of the best description of the universe.

Thus, the Sophisticated Regularity View counts as laws just those regularities that are described, or entailed, by basic statements of a particularly efficient description of the universe. As well as the ability to overcome the gold spheres problem, the Sophisticated Regularity View enjoys a high degree of continuity with actual scientific practice. Scientists are interested in discovering and articulating the most general and informative facts about the universe and in explaining as much as they can about the universe with as few resources as possible. The Sophisticated Regularity View takes this observation about scientific practice—that scientists seek strong simple explanations—and makes it constitutive of what it is to be a law of nature.

While continuity with science is generally seen as counting in favour of a philosophical theory of laws, some have expressed concern that the Sophisticated Regularity View's dependence on balancing *strength* and *simplicity* renders laws *mind-dependent*.

What counts as the best balance between the strength and simplicity of a description would seem to depend on contingent psychological facts about human beings. So, if human psychology were sufficiently different, then the system that struck the optimal strength-simplicity balance would be different, hence the *laws* would be different. However, the laws should not be contingent on human psychology, so the objection goes, so the Sophisticated Regularity View does not provide an appropriate philosophical account of the laws of nature. The defender of the Sophisticated Regularity View who does not wish to admit that laws are mind-dependent is thus tasked with developing wholly objective standards for evaluating the strength and simplicity of a description of the universe, but this is no mean feat.

I will briefly mention two further, but closely related, problems for the Sophisticated Regularity View, which have motivated the development of subsequent views to be discussed.

First, the Sophisticated Regularity View seems to get the order of explanation between laws of nature and facts about the universe the wrong way around. According to some philosophers, it is intuitively obvious that laws of nature explain facts about the universe: a dropped vase falls to the floor *because* of the law of universal gravitation; a light ray entering a prism exits the prism at angle θ *because* of Snell's Law; etc. However, according to the Sophisticated Regularity View, laws of nature merely *describe* facts such as those concerning falling vases and refracted light rays and so it looks as if facts about the world explain the laws of nature rather than the other way around.

A second, related, problem stems from the fact that had the world been very different from how it actually is, the laws of nature, according to the Sophisticated regularity view, would have been different too. Since it is *possible* that the world was very different, laws turn out to be highly *contingent* because the matters of fact that they describe are contingent. But perhaps we think that the laws of nature are *necessary*; that no matter how the world was, the laws would be just as they are.

Nomic Necessitation

Both regularity views are what philosophers would call "metaphysically lightweight"—they don't posit the existence of any unusual entities that are unfamiliar to common sense or modern science. This is not to say that they do not clash with common sense or science in other ways; we saw above that the Simple Regularity View bestows law status upon regularities that scientists would not deem laws. And both views arguably fail to capture the necessity and explanatory power of laws, features that some will say are why laws are so important to science in the first place. Furthermore, some philosophers have argued that quantum mechanical phenomena pose problems for the most influential versions of the sophisticated regularity view. The Nomic Necessitation view, to be discussed in this section, is less metaphysically lightweight, but its proponents think that this is justified by its other virtues.

The Nomic Necessitation view can be understood as agreeing with both regularity views that laws are regularities of the form "All Fs are Gs"; the disagreement lies in what *makes* a regularity a law. As before, the proponent of the Nomic Necessitation view will want to deem the regularities in LIST1 (plus "all gold spheres are less than 1 mile in diameter") *non-laws* and those in LIST 2 *laws*. To do this, they appeal to the idea that there exist such things as *universals* and *relations between universals*.

What are universals? One could think of universals as those entities in the world to which our predicates refer. So, just as names, such as "Aristotle" and "Napoleon" refer to the individuals Aristotle and Napoleon, *predicates* such as "…is red", "…is human", "…is massive" etc. refer to the universals *redness*, *humanity*, *mass*, etc. It is often said that individuals *instantiate* universals, where instantiation a special relation that holds between individuals and

universals. Take the example of a red post-box, the individual, the post-box, instantiates the universal, *redness*. Indeed, many different individuals can wholly instantiate the same universal—universals, unlike individuals, are multiply located and thereby account for respects of similarity between distinct individuals. Aristotle and Napoleon both instantiate *humanity*; post-boxes and cherries instantiate *redness*; electrons, bowling balls and black holes instantiate *mass*. In each of these cases, instantiating the same universal accounts for similarity between distinct individuals.

The nomic necessitation view also requires *relations* between universals. More precisely, the view requires *necessitation relations* between universals. To get a sense of what we mean by "necessitation relations between universals", consider the universals *redness* and *colour*. One might think that a necessitation relation holds between these universals because, *necessarily*, anything that instantiates *redness* instantiates *colour* too.

According to the Nomic Necessitation View, a regularity of the form "all Fs are Gs" is a law, if, and only if, there exist the universals *F-ness* and *G-ness* and a special kind of necessitation relation called a *nomic necessitation* relation, which we denote "*N*", between *F-ness* and *G*-ness, which ensures that anything that is F is G too.

Nomic necessitation relations, unlike the necessitation relation between *redness* and *colour*, hold only contingently. So, if it is a law that all Fs are Gs because *N* holds between *F-ness* and *G-ness*, it is nonetheless possible that *N* failed to hold and hence that it was not a law that all Fs are Gs. According to the Nomic Necessitation view, the necessity with which laws are associated is weaker than the necessary connection between *redness* and *colour.* This is thought by its proponents to be a benefit of the present view because, they think, although the laws of nature are necessary *in a sense*, they are not *absolutely* necessary because we can *conceive of* a world in which the actual laws do not hold (by contrast, we cannot conceive of a world in which something is red and not coloured) and conceivability is thought (by some) to entail possibility.

The Nomic Necessitation view deems "all uranium spheres are less than 1 mile in diameter" a law because, it says, there exists an *N*-relation that holds between the universals *being a uranium sphere* and *being less than 1 mile in diameter*; "all gold spheres are less than 1 mile in diameter" is not a law because there is no *N*-relation that holds between the universals *being a gold sphere* and *being less than 1 mile in diameter*.

Since the obtaining or not of an *N*-relation between two universals is a completely mind-independent matter, the Nomic Necessitation view, unlike the Sophisticated Regularity View, is not subject to the objection that the laws are mind-dependent. Furthermore, laws, on this view are said to explain matters of fact, rather than the other way around; it is *because* it is a law that all Fs are Gs, i.e., it is because an *N*-relation holds between *F-ness* and *G-ness*, that any particular F is also a G; N-relations play a *constraining*, or *governing* role which explains certain matters of fact.

Finally, laws, on this view, are said to enjoy the appropriate *necessity*; if *N* holds between *F-ness* and *G-ness*, then it is *necessary* that anything that is F is G too.

The Nomic Necessitation view is not without its problems. Perhaps the most straightforward source of concern is the fact that the view is not metaphysically lightweight. All of the work is done by *necessitation relations between universals*. But we are well within our rights to be sceptical about the existence of universals let alone necessitation relations between universals. What, exactly, *are* these things and are we really justified in believing in them? Universals and necessitation relations don't seem like other entities familiar to science. It's not as if we can discover universals and necessitation relations with a sufficiently powerful particle accelerator. Rather, they are entities posited by philosophers from the comfort of the armchair. But why think that the philosopher's armchair methods can license belief in such peculiar entities?

Relatedly, we may wonder how necessitation relations are supposed to do the work for which they are invoked by the philosopher. A necessitation relation, N's, holding between the universals *F-ness* and *G-ness* is supposed to make it necessary that all Fs are Gs. But why is this so? Why couldn't N hold between *F-ness* and *G-ness* and yet there still be an F that is not a G? As David Lewis, a staunch advocate of the Sophisticated Regularity View, memorably put the point in opposition to David Armstrong, a pioneer of the Nomic Necessitation View:

> I say that *N* deserves the name of 'necessitation' only if, somehow, it really can enter into the requisite necessary connections. It can't enter into them just by bearing a name, any more than one can have mighty biceps just by being called 'Armstrong'. (1983, 366)

Advocates of the Sophisticated Regularity view and the Nomic Necessitation view do, however, agree, in one important respect, about the nature of physical properties. Physical properties such as *charge*, *mass*, *spin*, etc. are important when it comes to the laws of nature because laws of nature seem to articulate regularities that are *about* these properties. Coulomb's law, for example, says that two distinct instances of charge will exert a force on each other proportional to the magnitude of each charge and inversely proportional to the square of the distance by which they are separated. The Sophisticated Regularity View maintains that laws, such as Coulomb's law, describe how properties are distributed throughout the universe and the Nomic Necessitation view maintains that laws are necessitation relations between universals that *determine* the distribution of properties throughout the universe—this, in essence, is the disagreement between these views. Where the two agree, however, is in the idea that properties *could*, in the very broadest sense of "could", be distributed in any way imaginable. They both agree that there is nothing about the property charge, for example, that determines how instances of charge are distributed and so nothing about charge that determines that instances of charge behave in accordance with Coulomb's law (similar comments apply to other property-law pairs).

This view of physical properties has been held up by some philosophers as a further source of concern for both the Sophisticated Regularity View *and* the Nomic Necessitation view. If physical properties are so "thin" as to impose no constraints on the laws that they enter into, it is hard to get a grip on what physical properties really *are*.

The contingency of the connection between properties and laws opens up the possibility that the property that we call "mass" featured in Coulomb's law and the property that we call "charge" featured in Newton's law of universal gravitation. In other words, it is possible that mass and charge swapped theoretical roles, which strikes many as very odd indeed. But worse still, since properties and the lawful behaviours with which they are associated is thoroughly contingent, there is no way of *knowing* which property or properties are playing which roles in our scientific theorizing about the laws—properties and their true natures are rendered irrevocably beyond our ken.

Dispositional Essentialism

Dispositional Essentialism takes as its starting point dissatisfaction with the thin view of physical properties shared by the Sophisticated Regularity view and the Nomic Necessitation view. Rather than conceiving of natural properties as thin and inert, Dispositional Essentialism maintains that properties have rich *essences*, which determine the laws that they enter into. So, in the same way that you or I may be said to be *essentially* human (but perhaps only accidently philosophers) properties are *essentially* certain ways too. *Laws*, then, are not imposed on properties, either as external descriptions or necessitation relations, rather they emanate from the essences of properties themselves because they concern property essences.

According to Dispositional Essentialism, a regularity such as "all Fs are Gs" is a law if, and only if, it holds in virtue of the *essence* of some property or properties. If it is part of the very nature of the properties F and G that *all Fs are Gs*, then it is a law that all Fs are Gs. If, on the other hand, all Fs are in fact Gs but this has nothing to do with the essence of any property, then the regularity is merely accidental and not a law.

Returning to our example, Dispositional Essentialism maintains that it is part of the *essence* of *charge* that charged individuals interact in accordance with Coulomb's law, i.e., that distinct charged individuals exert a force on each other proportional to the magnitude of the charges and inversely proportional to the square of the distance of separation. Since this is part of the essence of charge, it is not possible that charged individuals failed to interact in accordance with Coulomb's law. So, the odd result (yielded by the thin view of properties shared by the Sophisticated Regularity view and the Nomic Necessitation view) that charge and mass, for example, could swap roles and hence that we cannot ever know the true nature of physical properties, is avoided.

Dispositional Essentialism yields a simple response to the gold spheres problem too. It is *of the essence* of some property or properties that there are no uranium spheres greater than a mile in diameter, so it is a law that there are no uranium spheres greater than a mile in diameter. By contrast, there is no property or properties the essence of which makes it the case that there are no *gold* spheres greater than a mile in diameter, so it is merely an accident that there are no gold spheres greater than one mile in diameter.

There is no mind-dependence problem for Dispositional Essentialism; it is a completely mind-independent matter whether or not it is of the essence of some property that a given regularity holds, so laws of nature are completely mind-independent phenomena.

The question about *order of explanation*: "do laws explain matters of fact or do matters of fact explain the laws?" is arguably a vexed one for Dispositional Essentialism. If one interprets laws as describing the essences of properties, it looks as if matters of fact concerning properties and their essences explain the laws. If, however, one interprets laws as *constituents* of property essences, e.g., Coulomb's law is part of the essence of *charge*, then one could maintain that laws, so understood, constrain how properties are distributed through out the universe and, thereby, explain matters of fact. This way of viewing things is not so far from the Nomic Necessitation view—on the latter view, laws are necessitation relations between universals that constrain property distributions, on the former, laws are constituents of property essences that constrain property distributions. On both ways of looking at things, then, laws are metaphysical "constraining" entities that determine property distributions and hence determine and explain matters of fact. The obvious difficulty, then, for Dispositional Essentialism, and shared with the Nomic Necessitation view, is that of responding to the demand to say more about how, exactly, the laws are supposed to do this constraining work.

Assuming that Dispositional Essentialism's laws are up to their task, these laws turn out to be necessary in quite a strong sense. Laws concern the essences of properties, so, it is not possible in any sense for properties and the laws with which they are associated to come apart (compare: it is part of your essence that you are human so it is not possible for you to exist and not be human). Instances of charge must behave in accordance with Coulomb's law, for example, because Coulomb's law holds in virtue of the essence of *charge*. The Nomic Necessitation view, by contrast, allows that instances of charge may not behave in accordance with Coulomb's law if the relevant necessitation relation is not present.

Philosophers disagree on whether the necessity of the laws yielded by dispositional essentialism is an advantage or a disadvantage. Those who think that it is a disadvantage typically believe that conceivability, or what we can *imagine*, is our best guide to what's possible. They argue that since we can imagine instances of *charge* behaving in a way that violates Coulomb's law, it is not necessary that *charge* is governed by Coulomb's law. Others think that conceivability has nothing to do with what's possible and that the laws' being strongly necessary best explains why laws of nature are so important and useful, features that are hard to make sense of on the assumption that the laws are contingent. Some philosophers have even argued that the necessity of the laws yielded by Dispositional Essentialism does not go far enough because it still allows for the possibility of *alien* properties and laws—merely possible properties that are not actually instantiated anywhere or at any time and which are governed by completely unfamiliar laws—and this, they argue, severely compromises the laws' necessity and any potential benefit therein.

New Directions and Broad Issues

The philosophy of laws is a burgeoning field and I regret to have only been able to trace a limited number of lines through this fascinating area of research. I will, however, now briefly sketch some new research directions before concluding with a recap of the broad philosophical issues raised in this entry.

Structuralism

The philosophy of laws is entwined with the philosophy of *modality*, that is the philosophy of possibility and necessity. This was seen above in the discussion of whether and to what extent the laws are necessary. In general, we may think that laws play a role in determining the limits of what is possible. *Ontic Structural Realists*, motivated by developments in current physics, argue that the world fundamentally *is* a modal structure. That is to say, there are no individual objects at the fundamental level of the world, just modal structure. And when pressed on what they mean by this, they typically cite laws of nature. So, according to Ontic Structural Realism, laws of nature are the modal building blocks of our world.

Combination Views

Some philosophers have defended a combination of the Sophisticated Regularity View and Dispositional Essentialism. These Combination Views combine a broadly dispositional essentialist account of properties, according to which properties have rich essential natures that constrain how they are distributed, with the idea that laws of nature are features of an efficient *description* of property distributions throughout space and time. This combination, they argue, is able to avoid certain problems for regularity views and Dispositional Essentialism while also reaping benefits from both sides such as continuity with science (from the regularity view component) and the necessity and explanatory power of laws (from the dispositional essentialist component).

Pragmatism

There is a recent trend among some proponents of the Sophisticated Regularity View to, in a sense, embrace the partial mind-dependence of laws. These philosophers argue that laws ought to be useful tools for creatures *like us*; that part of what it is to be a law of nature is to be something that enables us to make predictions and facilitates the manipulation of our environment to our own ends. Since what counts as useful for us will, to an extent, depend on our *minds*, the laws are partially mind-dependent. But these philosophers think that this is as it should be if we are to provide a sensible philosophical analysis of laws that is genuinely continuous with actual science.

In sum, there are various issues of broad philosophical interest around which the question "what is a law of nature?" turns. These include the following. *Coherence with intuitions*: to what extent do we wish to accommodate, for example, the intuition that it is a law that all uranium spheres (but not gold spheres) are less than one mile in diameter? *Continuity with science*: to what extent do we want our account of laws to cohere with the scientific conception of laws? *Mind-(in)dependence*: can we tolerate a degree of mind-dependence of laws if this achieves continuity with science and perhaps other benefits, or must laws be completely mind-independent? *Metaphysical posits*: are we willing to accept the existence of universals, necessitation relations, property essences and governing forces if these yield certain benefits such as explanatory power and the necessity of laws? *Modality*: in what sense are the laws necessary and where does this necessity come from?

See Also: *Abduction; Conceptual Analysis; Explanation; Induction; Logic; Metaphysics; Philosophy of Science*

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