Essential Elements of Characterize the Laws of Nature - An Overview

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Abstract

This paper focus on Laws of Nature which are to be distinguished both from Scientific Laws and from Natural Laws. Albert Einstein famously believed that, given some general principles, there is essentially a unique way to construct a consistent, functioning universe. In Einstein's view, if we probed the essence of physics deeply enough, there would be one and only one way in which all the components — matter, radiation, forces, space and time — would fit together to make reality work, just as the gears, springs, dials and wheels of a mechanical clock uniquely combine to keep time.

The current Standard Model of particle physics is indeed a tightly constructed mechanism with only a handful of ingredients. Yet instead of being unique, the universe seems to be one of an infinitude of possible worlds. We have no clue why this particular combination of particles and forces underlies nature's structure. Why are there six "flavors" of quarks, three "generations" of neutrinos, and one Higgs particle? Furthermore, the Standard Model comes with 19 constants of nature — numbers like the mass and charge of the electron — that have to be measured in experiments. The values of these "free parameters" seem to be without any deeper meaning. On the one hand, particle physics is a wonder of elegance; on the other hand, it is a just-so story. If our world is but one of many, how do we deal with the alternatives? The current point of view can be seen as the polar opposite of Einstein's dream of a unique cosmos. Modern physicists embrace the vast space of possibilities and try to understand its overarching logic and interconnectedness. From gold diggers they have turned into geographers and geologists, mapping the landscape in detail and studying the forces that have shaped it. The game changer that led to this switch of perspective has been string theory. At this moment it is the only viable candidate for a theory of nature able to describe all particles and forces, including gravity, while obeying the strict logical rules of quantum mechanics and relativity. The good news is that string theory has no free parameters. It has no dials that can be turned. It doesn't make sense to ask which string theory describes our universe, because there is only one. The absence of any additional features leads to a radical consequence. All numbers in nature should be determined by physics itself. They are no "constants of nature," only variables that are fixed by equations (perhaps intractably complicated ones). Which brings us to the bad news. String theory's space of solutions is vast and complex. This is not unusual in physics. We traditionally distinguish between fundamental laws given by mathematical equations, and the solutions of these equations. Typically, there are only a few laws, but an infinite number of solutions.

Key words: physics, nature, newton, String theory, consequence, free parameters

Introduction

We do not expect, nor demand, an a priori unique solution that describes everything. In string theory, certain features of physics that we usually would consider laws of nature — such as specific particles and forces — are in fact solutions. They are determined by the shape and size of hidden extra dimensions. The space of all of these solutions is often referred to as "the landscape," but that is a wild understatement. Even the most awe-inspiring mountain vistas pale in comparison with the immensity of this space. Although its geography is only marginally understood, we know it has continents of huge dimensions. One of the most tantalizing features is that possibly everything is connected — that is, every two models are connected by an unbroken path. By shaking the universe hard enough, we would be able to move from one possible world to another, changing what we consider the immutable laws of nature and the special combination of elementary particles that make up reality. But how do we explore the vast landscape of physical models of the universe that might easily have hundreds of dimensions? It's helpful to visualize the landscape as a largely undeveloped wilderness, most of it hidden under thick layers of intractable complexity. Only at the very edges do we find habitable places. In these outposts, life is simple and good. Here we find the basic models that we fully understand. They are of little value in describing the real world, but serve as convenient starting points to explore the local neighborhood. A good example is QED, the theory of quantum electrodynamics that describes the interactions between matter and light. This model has a single parameter, called the fine-structure constant α, which measures the strength of the force between two electrons. In QED, all processes can be seen as arising out of elementary interactions. For example, the repulsive force between two electrons can be visualized as an exchange of photons.

QED asks us to consider all possible ways that two electrons might exchange a photon, which in practice would mean that physicists have to solve an infinite sum of great complexity. But the theory also offers a way out: Each additional photon exchange adds a term that includes α raised to an additional power. Since this is a relatively small number, the terms with many exchanges make only a small contribution. They can be neglected in an approximation to the "real" value. We find these weakly coupled theories at the outposts of the landscape. Here the strength of the forces is small and it makes sense to talk about the shopping list of elementary particles and the recipe that computes their interactions. But if we leave the immediate environment and travel more deeply into the wilderness, the couplings become large and each additional term in the expansion grows more important. Now we can no longer distinguish the individual particles. Instead they dissolve into an entangled mesh of energy like the ingredients of a cake in a hot oven. However, not everything is lost. Sometimes the path through the dark wilderness ends at another outpost. That is, at a different well-controlled model, this time made out of a completely different set of particles and forces. In such cases, there are two alternative recipes for the same underlying physics, just as with Alice and Bob's dishes. These complementary descriptions are called dual models, and the relation between them a duality. We can consider these dualities as a grand generalization of the famous particle-wave duality discovered by Heisenberg. For Alice and Bob, it takes the form of a translation between Chinese and Italian recipes.

Objective:

The main objective of this paper is to study Natural Laws, as invoked in legal or ethical theories, nor Scientific Laws, which some researchers consider to be scientists' attempts to state or approximate the Laws of Nature, will be discussed in this article. Instead, it explores issues in contemporary metaphysics.

Reductionism / Antireductionism fundamentals of scientific laws

John Carroll (1994, 2008), Marc Lange (2000, 2009), and Maudlin (2007) advocate antireductionist, antisupervenience views. (Also see Ismael 2014 and Woodward 1992.) Regarding the question of what it is to be a law, they reject the answers given by Humeans like Lewis, they deny Humean supervenience, and they see no advantage in an appeal to universals. They reject all attempts to say what it is to be a law that do not appeal to nomic concepts. Yet they still believe that there really are laws of nature; they are not antirealists.

Maudlin (2007, 17–18) takes lawhood to be a primitive status and laws to be ontological primitives — fundamental entities in our ontology. Then his project is to show what work laws can do, defining physical possibility in terms of laws and sketching law-based accounts of the counterfactual conditional and of explanation.

Carroll (2008) sketches an analysis of lawhood in terms of causal/explanatory concepts. The starting point is the intuition that laws are not accidental, that they are not coincidences. Not being a coincidence, however, is not all there is to being a law. For example, it might be true that there are no gold spheres greater than 1000 miles in diameter because there is so little gold in the universe. In that case, strictly speaking, that generalization would be true, suitably general, and not a coincidence. Nevertheless, that would not be a law. Arguably, what blocks this generalization from being a law is that something in nature — really, an initial condition of the universe, the limited amount of gold — accounts for the generalization. Contrast this with the law that inertial bodies have no acceleration. With this and other laws, it seems that it holds because of nature (itself).

Lange's (2000, 2009) treatment includes an account of what it is to be a law in terms of a counterfactual notion of stability. The overall account is intricate, but the basic idea is this: Call a logically closed set of true propositions stable if and only if the members of the set would remain true given any antecedent that is consistent with the set itself. So, for example, the set of logical truths is trivially stable, because logical truths would be true no matter what. A set that included the accidental generalization that all the people in the room are sitting but is consistent with the proposition that someone in the room shouts 'Fire!' would not be a stable set; if someone were to shout 'Fire', then someone in the room would not be sitting. Lange argues (2009, 34) that no stable set of sub-nomic facts — except maybe the set of all truths — contains an accidental truth. "By identifying the laws as the members of at least one non-maximal stable set, we discover how a sub-nomic fact's lawhood is fixed by the sub-nomic facts and the subjunctive facts about them" (2009, 43).

Attempts to undermine antireductionism often include challenges to antisupervenience like those mentioned at the end of Section 4. Tyler Hildebrand (2013) challenges Carroll's and Maudlin's antireductionisms based on the failure of primitive laws to explain the uniformity of nature. A symposium on Lange's (2009) Laws and Lawmakers includes, along with Lange's replies, a variety of criticisms from Carroll, Loewer, and James Woodward. (See Lange et al., 2011.) Heather Demerest (2012) raises three challenges to Lange's antireductionism all centered on whether subjunctives are suited to play the role of lawmakers.

Induction

Goodman thought that the difference between laws of nature and accidental truths was linked inextricably with the problem of induction. In his “The New Riddle of Induction” (1983, [f.p. 1954], 73), Goodman says, Only a statement that is lawlike — regardless of its truth or falsity or its scientific importance — is capable of receiving confirmation from an instance of it; accidental statements are not.(Terminology: P is lawlike only if P is a law if true.) Goodman claims that, if a generalization is accidental (and so not lawlike), then it is not capable of receiving confirmation from one of its instances.

This has prompted much discussion, including some challenges. For example, suppose there are ten flips of a fair coin, and that the first nine land heads (Dretske 1977, 256–257). The first nine instances — at least in a sense — confirm the generalization that all the flips will land heads; the probability of that generalization is raised from (.5)10 up to .5. But this generalization is not lawlike; if true, it is not a law. It is standard to respond to such an example by arguing that this is not the pertinent notion of confirmation (that it is mere “content-cutting”) and by suggesting that what does require lawlikeness is confirmation of the generalization’s unexamined instances. Notice that, in the coin case, the probability that the tenth flip will land heads does not change after the first nine flips land heads. There are, however, examples that generate problems for this idea too.

Suppose the room contains one hundred men and suppose you ask fifty of them whether they are third sons and they reply that they are; surely it would be reasonable to at least increase somewhat your expectation that the next one you ask will also be a third son (Jackson and Pargetter 1980, 423)

It does no good to revise the claim to say that no generalization believed to be accidental is capable of confirmation. About the third-son case, one would know that the generalization, even if true, would not be a law. The discussion continues. Frank Jackson and Robert Pargetter have proposed an alternative connection between confirmation and laws on which certain counterfactual truths must hold: observation of As that are F-and-B confirms that all non-F As are Bs only if the As would still have been both A and B if they had not been F. (This suggestion is criticized by Elliott Sober 1988, 97–98.) Lange (2000, 111–142) uses a different strategy. He tries to refine further the relevant notion of confirmation, characterizing what he takes to be an intuitive notion of inductive confirmation, and then contends that only generalizations that are not believed not to be lawlike can be (in his sense) inductively confirmed.

Sometimes the idea that laws have a special role to play in induction serves as the starting point for a criticism of Humean analyses. Dretske (1977, 261–262) and Armstrong (1983, 52–59, and 1991) adopt a model of inductive inference that involves an inference to the best explanation. (Also see Foster 1983 and 2004.) On its simplest construal, the model describes a pattern that begins with an observation of instances of a generalization, includes an inference to the corresponding law (this is the inference to the best explanation), and concludes with an inference to the generalization itself or to its unobserved instances. The complaint lodged against Humeans is that, on their view of what laws are, laws are not suited to explain their instances and so cannot sustain the required inference to the best explanation.

This is an area where work on laws needs to be done. Armstrong and Dretske make substantive claims on what can and can’t be instance confirmed: roughly, Humean laws can’t, laws-as-universals can. But, at the very least, these claims cannot be quite right. Humean laws can’t? As the discussion above illustrates, Sober, Lange and others have argued that even generalizations known to be accidental can be confirmed by their instances. Dretske and Armstrong need some plausible and suitably strong premise connecting lawhood to confirmability and it is not clear that there is one to be had. Here is the basic problem: As many authors have noticed (e.g., Sober 1988, 98; van Fraassen 1987, 255), the confirmation of a hypothesis or its unexamined instances will always be sensitive to what background beliefs are in place. So much so that, with background beliefs of the right sort, just about anything can be confirmed irrespective of its status as a law or whether it is lawlike. Thus, stating a plausible principle describing the connection between laws and the problem of induction will be difficult.

Necessity

Philosophers have generally held that some contingent truths are (or could be) laws of nature. Furthermore, they have thought that, if it is a law that all Fs are Gs, then there need not be any (metaphysically) necessary connection between F-ness and G-ness, that it is (metaphysically) possible that something be F without being G. For example, any possible world that, as a matter of law, obeys the general principles of Newtonian physics is a world in which Newton's first is true, and a world containing accelerating inertial bodies is a world in which Newton's first is false. The latter world is also a world where inertia is instantiated but does not necessitate zero acceleration. Some necessitarians, however, hold that all laws are necessary truths. (See Shoemaker 1980 and 1998, Swoyer 1982, Fales 1990, Bird 2005. See Vetter 2012 for criticism of Bird 2005 from within the dispositional essentialist camp.) Others have held something that is only slightly different. Maintaining that some laws are singular statements about universals, they allow that some laws are contingently true. So, on this view, an F-ness/G-ness law could be false if F-ness does not exist. Still, this difference is minor. These authors think that, for there to be an F-ness/G-ness law, it must be necessarily true that all Fs are Gs. (See Tweedale 1984, Bigelow, Ellis, and Lierse 1992, Ellis and Lierse 1994, and Ellis 2001, 203-228; 2009, 51-72.)

Two reasons can be given for believing that being a law does not depend on any necessary connection between properties. The first reason is the conceivability of it being a law in one possible world that all Fs are Gs even though there is another world with an F that is not G. The second is that there are laws that can only be discovered in an a posteriori manner. If necessity is always associated with laws of nature, then it is not clear why scientists cannot always get by with a priori methods. Naturally, these two reasons are often challenged. The necessitarians argue that conceivability is not a guide to possibility. They also appeal to Saul Kripke's (1972) arguments meant to reveal certain a posteriori necessary truths in order to argue that the a-posteriori nature of some laws does not prevent their lawhood from requiring a necessary connection between properties. In further support of their own view, the necessitarians argue that their position is a consequence of their favored theory of dispositions, according to which dispositions have their causal powers essentially. So, for example, on this theory, charge has as part of its essence the power to repel like charges. Laws, then, are entailed by the essences of dispositions (cf., Bird 2005, 356). As necessitarians see it, it is also a virtue of their position that they can explain why laws are counterfactual-supporting; they support counterfactuals in the same way that other necessary truths do (Swoyer 1982, 209; Fales 1990, 85–87).

The primary worry for necessitarians concerns their ability to sustain their dismissals of the traditional reasons for thinking that some laws are contingent. The problem (cf., Sidelle 2002, 311) is that they too make distinctions between necessary truths and contingent ones, and even seem to rely on considerations of conceivability to do so. Prima facie, there is nothing especially suspicious about the judgment that it is possible that an object travel faster than light. How is it any worse than the judgment that it is possible that it is raining in Paris? Another issue for necessitarians is whether their essentialism regarding dispositions can sustain all the counterfactuals that are apparently supported by laws of nature (Lange 2004).

Physics and the Special Sciences

Two separate (but related) questions have received much recent attention in the philosophical literature surrounding laws. Neither has much to do with what it is to be a law. Instead, they have to do with the nature of the generalizations scientists try to discover. First: Does any science try to discover exceptionless regularities in its attempt to discover laws? Second: Even if one science — fundamental physics — does, do others?

Do Physicists try to discover Exceptionless Regularities?

Philosophers draw a distinction between strict generalizations and ceteris-paribus generalizations. The contrast is supposed to be between universal generalizations of the sort discussed above (e.g., that all inertial bodies have no acceleration) and seemingly less formal generalizations like that, other things being equal, smoking causes cancer. The idea is that the former would be contradicted by a single counterinstance, say, one accelerating inertial body, though the latter is consistent with there being one smoker who never gets cancer. Though in theory this distinction is easy enough to understand, in practice it is often difficult to distinguish strict from ceteris-paribus generalizations. This is because many philosophers think that many utterances which include no explicit ceteris-paribus clause implicitly do include such a clause.

Even those who agree with the arguments of Cartwright and Lange sometimes disagree about what ultimately the arguments say about laws. Cartwright believes that the true laws are not exceptionless regularities, but instead are statements that describe causal powers. So construed, they turn out to be both true and explanatory. Lange ends up holding that there are propositions properly adopted as laws, though in doing so one need not also believe any exceptionless regularity; there need not be one. Giere (1999) can usefully be interpreted as agreeing with Cartwright's basic arguments but insisting that law-statements don't have implicit provisos or implicit ceteris-paribus clauses. So, he concludes that there are no laws.

Earman and Roberts hold that there are exceptionless and lawful regularities. More precisely, they argue that scientists doing fundamental physics do attempt to state strict generalizations that are such that they would be strict laws if they were true:

Our claim is only that … typical theories from fundamental physics are such that if they were true, there would be precise proviso free laws. For example, Einstein's gravitational field law asserts — without equivocation, qualification, proviso, ceteris paribus clause — that the Ricci curvature tensor of spacetime is proportional to the total stress-energy tensor for matter-energy; the relativistic version of Maxwell's laws of electromagnetism for charge-free flat spacetime asserts — without qualification or proviso — that the curl of the E field is proportional to the partial time derivative, etc. (1999, 446).

About Cartwright's gravitational example, they think (473, fn. 14) that a plausible understanding of the gravitational principle is as describing only the gravitational force between the two massive bodies. (Cartwright argues that there is no such component force and so thinks such an interpretation would be false. Earman and Roberts disagree.) About Lange's example, they think the law should be understood as having the single proviso that there be no external stresses on the metal bar (461). In any case, much more would need to be said to establish that all the apparently strict and explanatory generalizations that have been or will be stated by physicists have turned or will turn out to be false. (Earman, et al., 2003 includes more recent papers by both Cartwright and Lange, and also many other papers on ceteris-paribus laws.)

Could there be any Special-Science Laws?

Supposing that physicists do try to discover exceptionless regularities, and even supposing that our physicists will sometimes be successful, there is a further question of whether it is a goal of any science other than fundamental physics — any so-called special science — to discover exceptionless regularities and whether these scientists have any hope of succeeding. Consider an economic law of supply and demand that says that, when demand increases and supply is held fixed, price increases. Notice that, in some places, the price of gasoline has sometimes remained the same despite an increase in demand and a fixed supply, because the price of gasoline was government regulated. It appears that the law has to be understood as having a ceteris-paribus clause in order for it to be true. This problem is a very general one. As Jerry Fodor (1989, 78) has pointed out, in virtue of being stated in a vocabulary of a special science, it is very likely that there will be limiting conditions — especially underlying physical conditions — that will undermine any interesting strict generalization of the special sciences, conditions that themselves could not be described in the special-science vocabulary. Donald Davidson prompted much of the recent interest in special-science laws with his "Mental Events" (1980 [f.p. 1970], 207–225). He gave an argument specifically directed against the possibility of strict psycho-physical laws. More importantly, he made the suggestion that the absence of such laws may be relevant to whether mental events ever cause physical events. This prompted a slew of papers dealing with the problem of reconciling the absence of strict special-science laws with the reality of mental causation (e.g., Loewer and Lepore 1987 and 1989, Fodor 1989, Schiffer 1991, Pietroski and Rey 1995).

Progress on the problem of provisos depends on three basic issues being distinguished. First, there is the question of what it is to be a law, which in essence is the search for a necessarily true completion of: "P is a law if and only if …". Obviously, to be a true completion, it must hold for all P, whether P is a strict generalization or a ceteris-paribus one. Second, there is also a need to determine the truth conditions of the generalization sentences used by scientists. Third, there is the a posteriori and scientific question of which generalizations expressed by the sentences used by the scientists are true. The second of these issues is the one where the action needs to be.

On this score, it is striking how little attention is given to the possible effects of context. Mightn't it be that, when the economist utters a certain strict generalization sentence in an "economic setting" (say, in an economics textbook or at an economics conference), context-sensitive considerations affecting its truth conditions will have it turn out that the utterance is true? This might be the case despite the fact that the same sentence uttered in a different context (say, in a discussion among fundamental physicists or better yet in a philosophical discussion of laws) would result in a clearly false utterance. These changing truth conditions might be the result of something as plain as a contextual shift in the domain of quantification or perhaps something less obvious. Whatever it is, the important point is that this shift could be a function of nothing more than the linguistic meaning of the sentence and familiar rules of interpretation (e.g., the rule of accommodation).

Consider a situation where an engineering professor utters, “When a metal bar is heated, the change in its length is proportional to the change in its temperature” and suppose a student offers, “Not when someone is hammering on both ends of the bar”. Has the student shown that the teacher’s utterance was false? Maybe not. Notice that the student comes off sounding a bit insolent. In all likelihood, such an unusual situation as someone hammering on both ends of a heated bar would not have been in play when the professor said what he did. In fact, the reason the student comes off sounding insolent is because it seems that he should have known that his example was irrelevant. Notice that the professor’s sentence needn’t include some implicit ceteris-paribus clause in order for his utterance to be true; as this example illustrates, in ordinary conversations, plain old strict generalization sentences are not always used to cover the full range of actual cases. Indeed, they are rarely used in this way.

If special scientists do make true utterances of generalization sentences (sometimes ceteris-paribus generalization sentences, sometimes not), then apparently nothing stands in the way of them uttering true special-science lawhood sentences. The issue here has been the truth of special-science generalizations, not any other requirements of lawhood.

Conclusion

Why is this all so exciting for physics? First of all, the conclusion that many, if not all, models are part of one huge interconnected space is among the most astonishing results of modern quantum physics. It is a change of perspective worthy of the term “paradigm shift.” It tells us that instead of exploring an archipelago of individual islands, we have discovered one massive continent. In some sense, by studying one model deeply enough, we can study them all. We can explore how these models are related, illuminating their common structures. It is important to stress that this phenomenon is largely independent of the question of whether string theory describes the real world or not. It is an intrinsic property of quantum physics that is here to stay, whatever the future “theory of everything” will turn out to be.

A more dramatic conclusion is that all traditional descriptions of fundamental physics have to be thrown out. Particles, fields, forces, symmetries — they are all just artifacts of a simple existence at the outposts in this vast landscape of impenetrable complexity. Thinking of physics in terms of elementary building blocks appears to be wrong, or at least of limited reach. Perhaps there is a radical new framework uniting the fundamental laws of nature that disregards all the familiar concepts. The mathematical intricacies and consistencies of string theory are a strong motivation for this dramatic point of view. But we have to be honest. Very few current ideas about what replaces particles and fields are “crazy enough to be true,” to quote Niels Bohr. Physics is ready to throw out the old recipes and embrace a modern fusion cuisine.

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