Chapter 12: What Would Hume Say? Regularities, Laws, and Mechanisms[i]

Holly Andersen
Simon Fraser University
handerse@sfu.ca

Abstract: This chapter examines the relationship between laws and mechanisms as approaches to characterising generalizations and explanations in science. I give an overview of recent historical discussions where laws failed to satisfy stringent logical criteria, opening the way for mechanisms to be investigated as a way to explain regularities in nature. This followed by a critical discussion of contemporary debates about the role of laws versus mechanisms in describing versus explaining regularities. I conclude by offering new arguments for two roles for laws that mechanisms cannot subsume, one epistemically optimistic and one pessimistic, both broadly Humean. Do note that this piece is not primarily Hume exegesis; it is more of a riff in the key of Hume.

Keywords: mechanisms; laws, regularities; explanation; causation; Hume

I. Introduction

Contemporary discussion of mechanisms sprang from many failures of laws to do what philosophers of science wanted them to. Yet the expectations at that time for what laws should be able to do were impossible to achieve. Is there still room for a better construal of laws in understanding explanation and the nature of the world as studied by science, or do mechanisms provide everything that is required for scientific explanations? How do genuine laws relate to mechanisms in a mechanistic worldview?

After a survey of the discussion around laws and mechanisms, I offer an original argument for two main ways in which laws and mechanisms can relate without either conceptually or ontologically reducing to the other, using Hume to illustrate. The first connection between laws and mechanisms involves the recognition of the 'brute' character of laws, such that they can explain but are not themselves further explicable. This is illustrated by Hume's skeptical realism, where the world's hidden springs and secret principles are forever covered over from our epistemic access. The second connection between laws and mechanisms involves a unique role for laws via distinctively mathematical explanations, in which laws can provide a further degree of necessity, via mathematics, than can any collection of mechanisms no matter how comprehensive. This is illustrated in terms of the evidence for such laws, which may include the sort Hume labeled ‘relations of ideas’, rather than solely the type of evidence we have for mechanisms that Hume labeled ‘matters of fact’.

II. A short recent history of laws and mechanisms

Mechanisms as a characteristic form of explanation were originally developed as an alternative to a then-dominant way of understanding explanation as necessarily involving laws. The deductive-nomological model of explanation stated that explanations involve subsuming the explanandum (that which is to be explained) under a general law. The explanatory work was done by the law: event A led to event B because A was an F, B was a G, and all F’s are G’s (e.g. Hempel 1962). The explanans derived its power from the nomologicity of the law that figured in it. As such, laws needed to be general, or ideally, universal in that they apply everywhere at all times. They also needed to be more than merely true descriptions of what did or will happen. They had to involve a stronger degree of necessity, and convey what must happen, given those laws. Nomologicity is thus a kind of necessity that is stronger than mere actuality – it is more than what does happen; and it is weaker than what is sometimes called metaphysical or logical necessity, which involves what must or could not happen regardless of the laws.

In this potted mini-history, it is incredibly important to emphasize that the notion of laws that served in deductive nomological accounts of explanation were of a peculiar logical sort. Traditionally, laws have taken to be part of the world itself, and descriptions of those parts of the world yielded statements that had a special status as descriptions. The term 'law' would be equally applied to both the features of the world being described, and to the description itself. For instance, in the law F=ma, force, mass, and acceleration, as well as the necessary relationship between them, are all part of the natural world, and are a special part such that learning that such a relationship among those quantities holds allows us to make far more predictions than we otherwise could with individual cases of acceleration, mass, and force. The written mathematical form describing the relationship among the quantities, 'F=ma', is also called a law. As such, the term law applied to both the nomological features of the world and equally to the linguistic devices such as mathematical formulas used to describe those features of the world.

Laws were taken to bear the mark of their necessity in their very syntactic structure, so that only the schematic structure of the law, rather than its actual content or meaning, was required to identify a genuine law from a merely true generalization. Much work in the 20th century went into trying to find ways to represent laws as sentences in logical notation such that lawlike and non-lawlike statements were clearly differentiable by syntactic structure alone, without reference to actual content of the laws (e.g. Ayer 1956). Their idea was that laws in the world could be identified by their description. Genuine laws, and only laws, could be written out in logic, such that only the form of the sentence matter (All F's are G's) was required to identify such sentences as lawlike, without having to say anything about what the variables (the F and the G) stood for. This project failed, gruesomely (Goodman 1983). There is no unique logical structure of laws such that all and only laws, but no accidentally true generalizations such as "all the coins in my pocket are silver", have that structure.

This failure to find some logical structure unique to laws was fruitful in generating new ideas about what makes laws law-like, and about other forms of explanation that don't require such peculiarly structured laws nor deductive relationships. Laws in physics, even under best-case scenarios, do not resemble the logical creatures required for deductive-nomological accounts (e.g. Cartwight 1983). Unification of apparently disparate phenomena, for instance, is a historically well-substantiated form of explanation that does not rely on the logical notion of laws (Kitcher 1981). Explanations in the so-called special sciences were noted to rarely if ever use laws of the form presumed to be found in physics (Fodor 1974). Many causal explanations need not ever involve such laws (e.g. Woodward 2005, Strevens 2006).

This opened the way for mechanisms to gain attention as a key form that explanations take in certain sciences (e.g. Bechtel and Richardson 1993). Mechanisms differ from both the logically distinctive but mythical creatures sought for the D-N model of explanation, and from the best examples of actual laws found in physics and related disciplines. Mechanisms can be indefinitely local, particular, and contingent. They can proliferate in number, rather than be eliminated via reduction. They can serve explanatory roles for which laws, even if they were available, would be somewhat unsatisfactory and brute (Andersen 2011). Some authors, such as Glennan (1996), even argued that mechanisms could replace the characteristic kind of nomological necessity associated with laws.

It is important to recognize the heterogeneity of 'mechanism' in current discussions for reasons of clarity and philosophical precision. Some have argued that there is a growing consensus on the character of mechanisms (see especially the introduction to this volume, Ilari and Glennan). Others have argued that the situation is more of a muddle than a consensus, where very distinct senses of the term mechanism are used without sufficient care as to the differences between them (Andersen 2014a and 2014b). Minimally, there are relevant differences in emphasis between approaches to mechanisms. Some (e.g. Craver and Darden 2013) concentrate on the details of scientific practice and the role that mechanisms play in structuring discovery and investigation. Others (notably Glennan 2010) generalize the notion to offer a mechanistic worldview strikingly similar to those of the early modern era, which is more of an alternative to atomism or process ontology than it is an alternative to specific explanatory practices in contemporary science. Some take mechanisms to *involve* the notion of causation (such as Bogen 2005 and Machamer 2004) while other take mechanisms to *be* causation (such as Glennan 1996, or for a different notion of mechanism, Salmon 1998). Each of these conceptions of mechanism involves a different relationship to modal notions like nomologicity, which in turn changes the details of how such mechanisms are related to laws.

In order to leave as little metaphysical space, as it were, for laws, I will take the broadest possible construal of mechanisms (Glennan 2010) in order to push the question of what if any role for laws remains in such a mechanistic worldview. In such a construal, explaining the often surprisingly simple regularities in the world involves describing them with laws and then fleshing out laws with supporting mechanisms that explain *why* such lawfully-describable regularities hold. There are two views about the relationship between laws and mechanisms that might follow from this strongest construal of mechanism. On the first, laws are a useful step in describing regularities, but cannot be the last step, since laws themselves require explanation in terms of the mechanisms that support or sustain them. On the second view, mechanisms are a useful way to represent higher-level structures in the natural world, but they cannot themselves be fundamental, since if one were to go 'all the way down' with mechanisms, there would still be lawful connections between the elements or stages of a mechanism, such that the fundamental explanatory role would require laws and their nomologicity, which would remain brute in the sense of providing explanations but being themselves not further explicable.

If we focus on physics as providing the more fundamental account of the natural world, laws are often taken to be required for mechanisms. If we focus on biological sciences, laws and mechanisms appear more like distinctive stages of discovery, investigation, then explanation of patterns or regularities that are identified as phenomena of interest. It is a difficult and sometimes underappreciated task to even locate genuine regularities and describe them in a sufficiently precise fashion that they might qualify as a law in the first place (see also Mitchell 2000). Once a given regularity is identified and then described in terms of a law, though, that very law is itself a target for explanation. Why does this law hold? What conditions give rise to or sustain the regularity? Why do the relevant parameters have these value ranges rather than some other value ranges? Thus, a difference in initial emphasis between physics versus biology can yield a difference in how prominent laws versus mechanisms appear in terms of explanation and fundamentality.

III. Contemporary discussions of regularities, mechanisms and laws

The term 'regularity' is often used to highlight a feature of the world, so that it picks out regularly recurring patterns of behavior. Such regularities provide the grounds for individuating phenomena for description and investigation. Using a historical example, there is a regularity in the way in which heavy objects' velocities change after being dropped, such that Galileo labels it the Law of Odd numbers (Cohen 1985). He found a surprising regularity that depended only on how long the object had been falling, and not, for instance, on the size of the object, how large or small it was, and more. The regularity in question was formulated in terms of the amount by which the velocity increased between each time interval – it went up by 1 unit, then 3, then 5, and so on. This simple progression in the rate at which the velocity of dropped objects increased was surprising, generally observable for any object (for the right sorts of objects, anyways), and not merely a coincidence. The Law of Odd Numbers describes a particular regularity that we now know how to derive from the uniform acceleration of massive objects in a gravitational field. Galileo's version of the law is subsumed by Newton's version as a particular case of more general laws about mass, force, and acceleration. Newton's laws thus describe a different, more abstractly picked out, regularity, of which the regularity that Galileo described is a proper subset.

This example highlights how some degree of generalizability is required in order to qualify as a regularity. Regularities must be at least minimally regular, holding over some changes in a variety of background circumstances and potentially relevant parameters. When scientists move from identifying an intriguing regularity and calling the resulting description a law, there is a commitment to the belief that the observed regularity does not hold merely for the circumstances already observed, but *will* hold for unobserved and future circumstances. Importantly for the connection with mechanisms, we can be very mathematically precise about how an object described by the Law of Odd Numbers or Newton's laws will accelerate by knowing only a few parameters about the strength of the gravitational field, and without knowing anything about the way in which a gravitational field brings about acceleration. Thus, laws describe regularities in a way that commits to a certain scope of generalizability. Laws are regularities that *must* hold, rather than ones that happen to hold. It is this necessity that makes them especially useful in explanations and in understanding the underlying structure of the natural world.

However, generalizability does not necessarily require a law. There are many regularities in fields such as biology, sometimes expressed in mathematical terms, that are often taken to be generalizable and describable in mathematically precise ways. There are mathematical relationships regarding the distribution of traits across generation that hold across species and are taken to hold into the future as well. They must hold, with the necessity characteristic of laws rather than of accidental generalizations Yet these regularities don't seem to be part of the fundamental structure of the world; if we take laws to reveal the fabric of the world, then these generlizations fail to be part of it. Beatty (1995), for instance, has argued that if we ran the tape of evolution again, we would end up with a radically different outcome. Such incredible contingency seems at odds with the idea of lawfulness. If Beatty were right, then on the then-current understanding of laws, nothing in biology (or at least, no products of evolution) could be explainable by recourse to nomological necessity. This raised a pointed question for philosophers of biology about the status of generalizations in biology versus physics.

Are there such regularities as would require laws in biology? And would the resulting laws be of the same type as what goes under the name of law in physics? Cartwright (1983) has argued persuasively that even physics doesn't have the kinds of laws for which philosophers of science went looking in the 20th century. Rather try to get biological regularities to look like laws in physics, Mitchell (1997, 2000) argues for laws that apply to both physics and biology. This involves rejecting the binary dichotomy between full laws and mere accidental generalizations. Pragmatic laws are generalizations that are stronger than mere accidental regularities, but not as strong as universal, exceptionless laws.

The strength of pragmatic laws can be measured along multiple distinguishable dimensions. The first dimension is stability: across what range of background conditions and parameter values does the generalization hold? A generalization that holds under wider range of conditions is more stable, with the limiting ideal of the universal law that holds everywhere at all times. The stability of the conditions on which a law depends can vary, while nevertheless yielding generalizations that bear the right degree of necessity under the right conditions. The second dimension is strength: how strong is the necessity associated with the generalization, for the conditions under which it holds? At one extreme is the exceptionless law, which is never violated in its domain. But there may be generalizations that hold almost always that are used in a lawlike way, even though there are exceptions to them. A third dimension is degree of abstraction. Generalizations that are more abstract are those that ignore more the details, to pull out some more broad pattern across a wider range of concrete examples. Woodward (2010) makes a very similar point, but leaves laws behind in favor of causal generalizations.

This brings us to mechanisms. Mechanisms are often defined explicitly as providing explanations for regularities in nature: why those regularities occur in the conditions that they do, why they don't occur under other conditions, how the underlying entities and activities are organized and causally connected such that they produce as a final stage or give rise to and sustain the observed regularity for which an explanation is sought (e.g. Bechtel and Richardson 1993, Machamer, Darden, and Craver 2000). A model of a mechanism for a given regularity may provide the ability to make predictions about what would happen under new conditions.

This highlights one complementary role that laws and mechanisms can play in science. While laws describe regularities, mechanisms may go further and explain them. It is a difficult, and often underappreciated, task to precisely describe a regularity. Finding the right variables, the right way to relate them, and the right way to delineate the conditions of application, in the form of a law that is both accurate and can be used to make precise predictions, is itself a major scientific achievement. To say that laws describe regularities is not to diminish the work that laws can do. The task of describing via a law is not trivial; it is a huge breakthrough that is often itself a prerequisite for further work on that phenomenon. Investigations into the mechanisms responsible for a lawful regularity can yield the mechanisms that sustain, produce, or give rise to the regularity. Mechanisms explain why that regularity holds as it does, and how it is that instances of that regularity occur when and how they do.

It is vital to note that there need not be one mechanism = one law equivalence. Multiple distinct kinds of mechanisms may give rise to one lawful regularity. It might be that a particular law, as the precise description of a recurrent regularity that involves some degree of necessity, holds because of several distinct mechanisms operating under different circumstances. Conversely, there may be many different laws that turn out to involve the same underlying mechanism in different contexts. Maxwell's laws illustrate both directions of this. According to Morrison (2007), the formalism Maxwell used allowed him to provide quite general laws without specifying the variety of physical causes that might be involved in any given instance to which the laws apply allowing for multiple mechanisms underlying one law. At the same time, Maxwell's laws unified apparently disparate phenomena of electricity and magnetism, such that several older laws could be subsumed in terms of unified mechanisms of electromagnetism (e.g. p. 64).

Regularity can mean recurrent patterns of behavior that can be identified as phenomena of interest. There are also further notions of regularity that appears in discussions of mechanisms, focused on how tightly bound the stages of a mechanism are in order to count as a mechanism. Bogen (2005) has argued that regularity should not be a requirement on counting as a mechanism. Machamer, Darden, and Craver define mechanisms specifically in terms of regularity. "Mechanisms are regular in that they work always or for the most part in the same way under the same conditions." (200, p. 3) Bogen argues that there are mechanisms (or, what ought to count as mechanisms) that do not meet the requirement of “almost or for the most part”.

Bogen invokes the example of the release of neurotransmitter vesicles given the stimulation of the neuron. Only about 10% of vesicles, in the right start-up conditions, actually release neurotransmitter. According to the MDC definition, the case should not count as a mechanism, since the “always or for the most part” condition is not met. Yet this release is still a key part in the mechanism for transmitting a signal across the synapse. How tightly bound together must a series of causal processes be in order to count as a mechanism, rather than a mere coincidental collection of nearby interactions?

Bogen's aim is to push us towards a lower degree of regularity, such that the 10% counts as regular enough under the circumstances.

It is helpful to distinguish two possible loci of regularity at issue here: the degree to which a regularity exists in the world, as a phenomenon that could stand as the target of explanation; versus the degree of regularity within the mechanisms that explains such a phenomenon, where different organizations stages might have different probabilistic degrees of connection. I have responded (2012) to Bogen's challenge by arguing that mechanisms must be considered as at least minimally regular, in the sense of not being one-off causal chains, in order to be the target of *scientific* (rather than historical, for instance) explanation. If mechanisms are to do explanatory work for individual occurrences of a mechanism, it must be by dint of situating that individual instance as a member of a type of occurrence. A taxonomy of different degrees of regularity, and locations different organizational stages of the mechanism, can convey a great deal of information about mechanism(s), and provide additional phenomena requiring further explanation. For example, the 10% figure for vesicle neurotransmitter release is part of a larger, embedding mechanism that essentially uses the 10% rate to calibrate neurotransmitter to reduce noisy synapse firings. Thus, the purportedly irregular 10% release rate is a consistent regularity in the other sense, that of a recurrent pattern of behavior requiring explanation for which a mechanism can be sought.

Notice how important the issue of generalization has been for construing the relationship between mechanisms and regularities. The very idea of a regularity contains within the notion of recurrence: a singular event, that will only happen once, cannot be a regularity, and thus cannot be explained as a regularity. Insofar as it is situated within a group of other possible instances, even if they are only merely possible instances, it is already being treated as a kind of regularity.

Thus far, the relationships between laws and mechanisms has been more complementary than competitive. There is one contemporary debate that does pitch mechanisms amd laws as competitors in the explanation business. A mechanism can explain why a law holds, and a law can connect the stages within a mechanism. Which is more explanatorily fundamental, mechanisms or laws? Suppose some regularity is identified and described as lawful. Further investigation turns up a mechanism that explains how that lawful regularity holds. But this mechanism is comprised of organized entities and processes that are themselves lower level lawful regularities. The mechanism that explained the original law requires further laws for its own operation. And each such law might be further explained by a mechanism, and the stages of *that* mechanism must involve laws to connect them, and so on downwards.

Where does this end? There are two main options. It could terminate with laws of physics at the most fundamental levels, such that there are no further mechanisms that could be posited to underlie the laws. They would be brute, in that they could explain but not be themselves explained; they would simply hold of the world. On the other option, even the laws of physics could themselves be mechanistically explained, such that mechanisms would be ontologically and explanatorily fundamental.

This framing of the question has several notable features, regardless of the eventual answer. The first is that it emphasizes the ontological or even metaphysical aspects of the question. It is not merely a question of what explains what. The explanatory consequences follow from ontological priority. A second feature is that the framing presupposes that either laws, or mechanisms, but not both, are ontologically primitive. This puts laws and mechanisms in a kind of explanatory competition, where it must be the same explananda that both endeavor to explain, but where there is only room for one genuine explanation, and only these two options on the table. A third feature is that it lacks criteria by which this question would be adjudicated. If string theory, for instance, turns out to provide the material for a grand unified theory, are the core features of the world that it postulates mechanisms or laws? How much change to the notion of mechanism would be required to accommodate such a heavily mathematical theory? At some point of stretching the meaning of mechanism to fit mathematical models, it simply can't be the same kind of mechanisms as are posited to explain the firing of a synapse (although a different conclusion is reached by Kuhlamnn and Glennan 2014) .

Finally, raising the question in terms of *laws* versus mechanisms elides the issue of *causation* versus mechanisms, or even in terms of nonmechanistic causation versus mechanistic causation. Mechanisms and counterfactuals are also taken to be opposing potentially ultimate categories (see especially Psillos 2004, Bogen 2005, Machamer 2004, Woodward 2005, Glennan 2010, and chapters 10 and 11 in this volume). The opposition is strikingly similar: counterfactuals govern the relationships between elements or stages in a mechanism, but those counterfactuals can be cashed out with yet-lower level mechanisms, and so on.

In these discussions of regularities, there is a kind of modal bump in the rug. This bump is the 'oomph' that has been associated with causation, or the nomologicity that has been associated with laws, or the intricate architecture of a mechanism. The bump in the rug can be shifted, depending on other philosophical considerations, to be located at laws, causation, or mechanisms, but it has proven remarkably hard to just stomp it flat. When some regularity holds and we have reason to think that it would hold if poked and prodded in various ways, we need a way to capture the extra content that goes above and beyond merely describing what actually happened. This is not a merely semantic point: if some particular event really did have to happen a certain way, rather than merely happening to happen, leaving that out would be an incomplete description. Insofar as science is in the business of working towards not merely accurate but also complete descriptions of various parts of the natural world, it must be able to note these modal characteristics in a way that accurately portrays the degree of connection.

Where Mitchell offered pragmatic laws to do this work in fields such as biology, others such as Woodward (2010) offer very similar considerations, including scope, specificity, and stability, for causal generalizations in biology. Cartwright (2002) notes how discussions of explanation and scientific theories tried to eschew talk of causation by using talk of laws, and how that pendulum has now swung back to causation. Lewis' account of causation is based on regularities; Salmon's is based on mechanisms. Glennan (1996) also turns to mechanisms for causation.

There is an incredibly close link between laws and causation as the two leading candidates to account for the degree of connection or necessity beyond mere accident that we find in many of the most interesting generalizations in the sciences. We can attribute this necessity to causation, and cash it out one way, or to laws, and cash it out a different way. In this regard, either laws or causation, but not both, are required. This is not a tension per se, in that it needn't mean that *only* one of laws or causation are required (for instance, the idea of causal capacities or powers involve both, see chapter 10). But it tends to go along with relying on one or the other to do the work of accounting for necessity and connection.

IV. Two Humean roles for laws

We've now explored several subtle connections between laws and mechanisms as ways of explaining regularities in the world that bear some degree of necessity. In this section, I will lay out a schematic argument for two roles unique to laws that cannot be assimilated to mechanisms. Taking the broadest possible construal of mechanisms, and the weak construal of laws, consider: can mechanisms, if construed maximally broadly, do all the work that we wanted from laws, or is there still a role left for laws no matter how broadly one construes mechanism? This question is both perennial, in that it has arisen in a number of forms in philosophy since the early modern period, and Humean, in that it often arises anew in discussions of well-loved passages from Hume. I rely on Hume as a springboard for making the case for two new ways in which laws and mechanisms could relate, since both appear in his work. This is not Hume exegesis: I take it that no unambiguous answer can be given to the question of what Hume himself would actually say. Instead, this is a riff on Humean-style answers as a way of illustrating the point.

As Beebee (2006) has persuasively argued, there are at least two viable ways of understanding what Hume says about causation, and no further definitive answers about which is what he 'really' meant (if we are even willing to assume Hume had a single consistent view across all his writings). One interpretation developed by Beebee is that Hume was a skeptical realist. The secret connection, which might bind cause and effect or primary and secondary quality, the connection that is tracked by the idea of force and purportedly conveys necessity along its chain – to a skeptical realist, such a secret connection exists, but the world is such that we are in principle barred from ever gaining genuine epistemic access to it. It *exists*, but we can't *know* it.

> It is confessed, that the utmost effort of human reason is to reduce the principles, productive of natural phenomena, to a greater simplicity, and to resolve the many particular effects into a few general causes, by means of general reasonings from analogy, experience, and observation. But as to the causes of these general causes, we should in vain attempt their discovery; nor shall we ever be able to satisfy ourselves by any particular explication of them. These ultimate springs and principles and totally shut up from human curiousity and enquiry. (Hume [1748] 2007, p.)

To the skeptical realist, laws may serve as the "the few general causes", the most general explanation that science may reach. These laws describe the phenomena that are produced by the "ultimate springs and principles". Yet the springs and ultimate principles themselves, the mechanisms producing those laws, is "totally shut up" from our investigations, off limits to knowledge.

In other passages, Hume denies that any amount of knowledge of what we would now call mechanisms is sufficient to discern what might happen with further instances prior to actual observation.

> Our senses inform us of the colour, weight, and consistence of bread; but neither sense nor reason can ever inform us of those qualities which fit it for the nourishment and support of a human body….
> The bread, which I formerly eat, nourished me; that is, a body of such sensible qualities was, at that time, endued with such secret powers: but does it follow, that

> other bread must also nourish me at another time, and that like sensible qualities must always be attended with like secret powers? The consequence seems nowise necessary. (Hume [1748] 2007, pp. 33.)

Students encountering this passage for the first time often wonder what Hume would say in the face of modern science. Once we know the mechanisms by which chemicals interact with the microscopic processes in our digestive tracts, wouldn't we know whether a new piece of bread, or even an entirely new foodstuff given straight to scientists before eating, would harm us or nourish us? There is an intuitive appeal to the idea that this is a problem on which actual progress has been made by science – the secret powers of food are not so secret anymore.

But Hume himself considers this question. Experience has led us to understand some mechanisms about nourishment, certainly; but even those rest on further sensible qualities that ultimately must be supported by the hidden powers and secret connections that Hume is challenging. Food science merely defers the problem. It does not and cannot solve it.

One needn't even commit to the realist part of skeptical realism, leaving laws as sheerly brute. If there are no such hidden springs, the result is still skepticism that precludes any possible mechanistic explanation of laws. Thus, the first Humean role for laws is an especially poignant one. It allows for the possibility that there *are* mechanisms underneath the fabric of the universe, and it is these mechanisms that give the modal oomph to those laws by providing the secret connection. Yet they remain out of reach, if they even exist. The laws that are the last description of regularity before those hidden springs will remain brute, in that they can explain, but cannot be themselves explained. Even in the face of massive amounts of contemporary human knowledge of mechanisms, these ultimate regularities cannot be assimilated to them.

The second Humean role for laws that cannot be assimilated to mechanisms stems from the evidence for relations of ideas versus for matters of fact. The first role for laws, just discussed, is squarely within the realm of matters of fact: facts about regularities that are described lawfully, resolved into mechanisms, but ultimately come up against the opacity of the hidden springs. The second role for laws involves their status as mathematical relationships that fall at least partially under the category of relations of ideas and thus have additional evidentiary support compared to matters of fact

Hume very famously distinguishes between knowledge in terms of the target of inquiry.

> All the objects of human reason or enquiry may be naturally divided into two kinds, to wit, *Relations of Ideas*, and *Matters of fact*. Of the first kind are the sciences of Geometry, Algebra, and Arithmetic; and in short, every affirmation which is either intuitively or demonstratively certain. ..Matters of fact, which are the second objects of human reason, are not ascertained in the same way; nor is our evidence of their truth, however great, of a like nature with the foregoing. The contrary of every matter of fact is still possible; because it can never imply a contradiction… (Hume [1748] 2007, p. 25)

He considers the kind of evidence we could have for the truth or falsity for claims about matters of fact versus relations of ideas Since the contrary of any factual claim is not contradictory, we cannot use contradiction as a guide to truth and falsity for these claims, but must rely on evidence of the senses. "All reasonings concerning matter of fact seem to be founded on the relation of *Cause and Effect*. By means of that relation alone we can go beyond the evidence of our memory and senses" (ibid, p. 70) And of course, reasoning based on cause and effect is ultimately founded on sheer habit. It is in this gap between what we infer about matters of fact, and that from which we infer it, that Humean skepticism arises.

In contrast, relations of ideas have an entirely different evidentiary status. They do not ultimately rest on mere habit. They do not admit of the skepticism about knowledge to which matters of fact are subject. Claims about relations of ideas can be known with certainty and assurance, because their contraries are contradictions and therefore impossible. The claim I am offering here is that there is at least the possibility for mathematical laws to have some evidential support that is of the form for relations of ideas, and thus not reducible to mechanisms (do note this is an original argument about how to apply this distinction to laws, not a existing view in Humean scholarship).

Consider laws that are formulated mathematically (setting aside non-mathematical laws for now). Laws that are supported by evidence that is at least partially mathematical in character will have a different status than those based purely on matters of fact, even if the other part of the evidential support is drawn from matters of fact. Laws can be used in ways that rely on their mathematical features to draw conclusions that involve a markedly higher degree of necessity that mere nomologicity can convey, even though those same laws, used some other way, behave in a traditional way, conveying nomological but not mathematical necessity (for instance, see Lange 2013 and Andersen 2016).

Consider what "relations of ideas" evidence might be available for a candidate mathematical law. Insofar as a law is derived from other mathematical laws, plus additional mathematical machinery, some of the evidence for the new law taking the form that it does is drawn from those mathematical relationships. Not all of the evidence for such a law is. Any law with genuine physical content will require at least some evidence of matters of fact. The point I want to make is that some of those laws may *also* have additional evidentiary support from relations of ideas, and that such additional support is not even potentially available for mechanisms.

An intriguing potential example of this is leading versions of string theory, where this second Humean role for laws can account for why string theory is even being pursued as a viable physical theory depiste the well-known lack of empirical confirmation. There is widespread agreement that string theory is not supported by empirical evidence, since it is extraordinarily difficult to even find ways to derive empirical predictions from it. In other words, string theory lacks evidence of matters of fact. Why is it even being considered as a potential theory, much less a fundamental one? The mathematical structures themselves, and the ways in which some mathematical relationships emerge as lawfully governing any such structure in the world, provide the kind of evidence that physicists find sufficiently compelling to continue working on it. This evidence is in the category of relations of ideas.

There is thus a philosophically pessimistic and a philosophically optimistic role for laws to play that cannot be assimilated to mechanisms, no matter how broadly construed. Each of these two roles have a distinctively Humean flavor. Pessimistically, laws might be brute and not further explicable; we can never know if mechanisms behind those laws even exist, much less what they are. Optimistically, laws can play a unique role by dint of mathematical relationships: this yields mathematical necessity as part of the nomologicity of laws, and an additional potential source of evidence, relations of ideas, that is not susceptible to inductive skepticism.

V. Conclusion

It is helpful in many contemporary discussions involving laws, mechanisms, regularities, and even causation, to consider the recent trajectory of these ideas since the mid-20th century. The idea of a law was supposed to do an enormous amount of work in the development and use of scientific theories. Peculiarities in views about the nature of language painted philosophers into a corner. Laws were expected to shoulder the burden of explanation and to clarify nomologicity in logical terms. This impossible task failed, in interesting ways, not least of which was that it cleared the ground for mechanisms to surge as a locus of research for philosophers of science trying to capture the investigatory and explanatory practices of sciences like biology.

Yet alternative construals of laws, including but not limited to Mitchell’s pragmatic laws, continue to offer something unique in terms of capturing the right degree of necessity associated with many scientific claims. I have argued here for two new ways to think about the relationship between mechanisms and laws. One is pessimistically Humean, where there may or may not be ultimate mechanisms under the very fabric of the universe which give rise to the laws, but which, if they even exist, are in principle locked away from us. The second is optimistically Humean, where mathematically formulated laws can offer a way to evade inductive skepticism at least partially, by relying on evidence drawn from mathematics, or, from the relations of ideas rather than matters of fact.

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