Introduction “What Breathes Fire into the Equations?”

The idea that the universe is governed by laws of nature has precursors from ancient times, but the view that it is a primary - or even *the* primary - aim of science to discover these laws only became established during the 16th and 17th century when it replaced the then prevalent Aristotelian conception of science. The most prominent promoters and developers of the new view were Galileo, Descartes, and Newton. Descartes, in *Le Monde* dreamed of an elegant mathematical theory that specified laws that describe the motions of matter and Newton in his *Principia* went a long way towards realizing this dream.

Historians of science agree that the emergence and development of the idea of a law governed universe were strongly influenced by 17th century theology, and especially by the view that matter is passive and that God’s will is the source of all motion and activity.[[1]](#footnote-1) This contrasted with the Aristotelian account according to which the universe consists of many different kinds of active entities each with their own powers and capacities. The paradigm science for Aristotle was biology which studies living beings whose natures it is to move, each in their own ways. By contrast, in the law governed view of the world, the motions of material objects are due entirely to the operation of laws that carry out God’s will. The historian Peter Harrison writes:

Unlike the ontologically rich Aristotelian world, the sparse world of atoms or corpuscles was unpopulated by the qualities, virtues, active principles, and substantial forms that had once invested nature with significant causal agency. This was a causally vacant cosmos that would be receptive to the direct volitions of the Deity. (reference?)

Samuel Clarke, Newton’s spokesman in his debate with Leibniz, called laws “God’s volitions”. They are the source of all motion. Descartes thought that laws could be expressed as theorems of a system characterized by a few mathematical axioms that covered the motions of all matter. In his *Principia* Newton showed how. His laws are simple, mathematical, eternal, universal, exceptionless and deterministic. These features were thought to reflect God’s eternal, omnibenevolent, omnipotent, omnipresent, and omniscient nature. On this view, laws both systematize and govern the world in accord with God’s plan.[[2]](#footnote-2)

Without Newton, Descartes dream might have died. Instead, it initiated a program that led to electromagnetic theory, statistical mechanics, relativity, quantum field theory, and in the twentieth century evolved into Steven Weinberg’s dream of a final theory: a theory that specifies the universe’s fundamental ontology and a system of laws that cover every event occurring in space-time.

The idea of laws as deterministic and universal set the stage for diminishing the role of God in science. If the universe is governed by such laws, it can be imagined, as Boscovich and Laplace did, that God sets the initial conditions and then leaves it to the laws to do the rest.[[3]](#footnote-3) Except for an occasional miracle, He no longer needs to be involved in His creation. Forces replaced God as the causes of motion although their operation was still subject to mathematical principles. The picture of laws evolving the universe without God’s governance allowed scientists to imagine laws entirely without God. Even though we still speak of laws “governing”, since there is no governor, this is understood by most as a metaphor.

But then one may wonder, if laws are not God’s volitions, what are they? And if governing is just a metaphor, how are laws enforced? John Foster argued that if there is no God there are no laws and used this to argue for God’s existence.[[4]](#footnote-4) Nancy Cartwright agrees with Foster’s conditional but reversed her inference to argue against the existence of laws. Her view is that if the theological assumptions that provided the underpinning of the idea of laws are no longer taken seriously, the concept should be abandoned.[[5]](#footnote-5) Unlike Cartwright, I think that the idea of laws of nature is required to understand physics and other sciences and that it also plays a central role in understanding the metaphysics of space and time, fundamental ontology, causation and chance. Unlike Foster, I think the concept of laws of nature can survive without relying on theological assumptions. Say here that instead of the governing idea you have the systematization idea. This book examines some current accounts, and offers a new account, of how this can be done.

The idea of chance also emerged during the 16th and 17th century although it too has precursors going back to ancient times. God’s hands were seen here as well but in ways that seem to defy predictability about individual events while arranging for stable long-term frequencies.[[6]](#footnote-6) The first applications of the concept of chance were to gambling, actuarial tables, agriculture, finance and other mundane matters that seem far removed from the celestial motions that were the domain of Newton’s laws. For much of the 17th and 18th centuries, the domains of law and chance hardly overlapped and chance played little role in physics. But by the 20th century, chances are found throughout the biological and social sciences, and in physics laws of nature and chance came together in statistical mechanics and quantum mechanics.

Chance’s birth year is usually given as 1654 - the year of a famous correspondence between Pascal and Fermat that concerned how to settle the winnings in an interrupted gambling game.[[7]](#footnote-7) Solving this problem involved developing a concept that -as Ian Hacking puts it, is “Janus faced.” One face looks to the world and the other to the mind. It says something about the world - the chance of the outcome of the toss of dice - but also something about what degree of belief we should have about what it is a chance of. Most accounts of chance characterize it in terms of one or the other aspect and then try to explain or explain away the other aspect. But as Hacking emphasizes the two faces are inseparable. Chance is the objective feature of the world that guides subjective belief and action. David Lewis’ formulated a principle about how chance should guide belief that says in effect that degrees of belief should match the chances. The primary philosophical question about chance is “What feature of the world could be like that? A related question is “How is chance related to laws of nature and in particular, what room is there for chance if the fundamental laws are deterministic?” The account I will discuss provides answers to these questions by unifying the metaphysics of laws and chances.

If not God then what, as Steven Hawking asks, is it that “breathes fire into the equations? My answering this question first involves surveying the most prominent contemporary accounts of laws and chance. I will then propose a novel version of David Lewis’ Best Systems Account of laws and chances (BSA). My account, which I call the package deal account (PDA), differs from Lewis’ in that while his is built on a metaphysically given ontology of fundamental properties, the PDA incorporates laws, chances, fundamental ontology, and space-time into a package of mutual interdependence. Like Lewis’ BSA, the PDA claims that a proposition expresses a law in virtue of its role in a scientifically optimal systematization, but it is not committed to Lewis’ version of Humean metaphysics. Because of this, it avoids some of the problems that confront Humeanism and includes elements of other accounts??? and since it replaces metaphysical presuppositions with scientific accounts, it advances the project of “naturalizing metaphysics. I will argue that the PDA better captures how laws, chances, and fundamental ontology are understood in physics.

Chapter 1

 The concept of fundamental law of nature that emerged during the 17th century in physics contained two main components. One is that laws are expressed by mathematical principles that cover and systematize fundamental events. The second is that laws in some way govern these events. In the17th century, the systematizing involved in laws was thought to reflect God’s nature and the governing was thought to be based on God’s power and activity. Contemporary approaches to the metaphysics of laws and chances are divided into two camps, called Humean and non-Humean. One can see contemporary Humeans as emphasizing the systematizing aspect, while rejecting the governing aspect, and contemporary non-Humeans as emphasizing governing without relying on theology.

According to Humean metaphysics, the universe is composed of a distribution of fundamental properties and relations within a space-time structure and laws are theorems of a system that systematizes this distribution. Necessary connections are nowhere to be found in fundamental reality. The rejection of *fundamental* necessary connections is the reason the view is called “Humean.” According to Humeans, whatever necessity there is in nature is constructed from the materials of the actual distribution of fundamental events.

Non-Humean accounts of laws disagree. They hold that laws involve fundamental necessity. There are two main kinds of non-Humean accounts i) governing accounts and ii) powers accounts. The first construe laws and chances as elements of reality over and above the Humean mosaic that in some way govern or direct it. Fundamental necessity is involved either in characterizing laws, or characterizing governing, or both. The second kind of non-Humean holds that not all fundamental properties are categorical but that some are dispositions or essentially possess powers that produce instantiations of properties in distinct space time regions and the activity of these powers forge necessary connections between events. Laws are the regularities that result. Both types of non-Humean accounts find fundamental necessity in nature in contrast to Humeans who, if they speak of necessity, consider it to be derived.

Non-Humean accounts of chance understand it along the lines of a measure of degree of possibility or propensity. Either laws or properties determine the propensity. Chances so understood don’t govern but rather guide the evolution of events. THIS IS TOO CONDENSED. In contrast, Humean accounts of objective chance understand chances as summarizing or supervening on the distribution of events. An actual frequency account is an example of a Humean account of chance but, as we will see, there are more sophisticated accounts. While one could imagine holding a non-Humean account of laws and a Humean account of chances it is natural that accounts of the two go together.[[8]](#footnote-8) We discuss laws in this chapter and chance in the next.

Governing Accounts of Laws:

 Contemporary governing accounts of laws replace the Deity with something else that does the governing. David Armstrong proposed necessitation relations between universals for the job. Universals are entities that determine properties that are not themselves individuated in terms of laws.[[9]](#footnote-9) I don’t understand this about universals The generalization “Every F is followed by a G” expresses a law iff F and G are universals that are related by a relation Armstrong calls “contingent necessitation” N(F,G). Given the occurrence of an F, N(F,G) produces the occurrence of a G. N(F,G) is contingent because it is metaphysically possible for F and G to be instantiated even though they are not related by N. However, according to Armstrong, it is not metaphysically possible for N(F,G) to obtain but (x)(F🡪G) to be false. Since N(F,G) guaranties that Fs are followed by Gs it is supposed to explain why Fs are followed by Gs. Bas van Frassen calls the problem of demonstrating that N(F,G) implies (x)(Fx🡪GX) “the inference problem.” Armstrong doesn’t see how to solve it but simply accepts it, as he says “with natural piety.” Thus, N(F,G) replaces God in governing the world.

 There are two big problems with Armstrong’s account, as an account of fundamental laws of physics. The first is that the laws of temporal evolution in contemporary physics, like Hamilton’s equations, the Schrödinger equation, and the field equations of general relativity don’t relate Armstrong type universals. Instead, they specify how the entire state of an isolated system (or the entire universe) evolves or is constrained. Dynamical laws are what Maudlin calls FLOTES- fundamental laws of temporal evolution that specify the evolution of the fundamental state of a system. Armstrong could take this into account by stipulating that the relation of contingent necessitation holds between entire states of the universe or states within a light cone, but this is very different from his original account, since states are different from his universals.

The more serious problem was alluded to before. It is that we have no account of what N(F,G) is and how it is that it makes it the case that Fs are followed by Gs. One could insist that it is simply analytic that if N(F,G) then Fs are followed by Gs. But if the implication is true by meaning it seems to undermine the ability of N(F,G) to *explain* why Fs are followed by Gs. So, what is the relation? It isn’t the case that N(F,G) causes Fs to be followed by Gs. N(F,G) is not the sort of entity that is involved in causation and, in any case, since causation involves subsumption under laws. this would require laws involving N(F,G) and so just postpone the problem. To make it the case that N(F,G) guarantees and explains why Fs are followed by Gs would seem to have to involve some kind of *sui generis* explanatory relation. But where Descartes, Newton, and their contemporaries might have thought they understood how God could bring about worldly regularities, we have to admit that we have no idea how N(F,G) works to make Gs follow Fs.

Also, one may wonder why scientists should be interested in discovering that N(F,G) or why N(F,G) is related to counterfactuals and explanation in the ways that we think laws are. Just declaring that these facts are laws doesn’t answer the question. N(F,G) has to earn that title not merely assume it.

A different governing account of laws more in tune with contemporary physics has been proposed by Tim Maudlin. According to Maudlin, the fundamental laws of physics are themselves metaphysically fundamental elements of ontology. They are entities, in a very broad sense, although they don’t fall into any of the usual ontological categories, properties, relations, individuals, space-time, abstract mathematical structures, etc. Maudlin thinks we should recognize laws as belonging to a *new* category of ontology. They are entities that *produce* or *govern* and thereby *explain* the evolution of events. They do this by operating on the state of the universe at a time (or on a Cauchy surface) and producing from it states at subsequent times. Exactly how this works is not further explicated but posited as the best account of laws in physics. This account has the interesting feature of presupposing a preferred temporal direction in which laws operate. Maudlin thinks this is an advantage of his account since there are other reasons to hold that as, he put, “time passes” in the direction of past to future. On his account, time is the unique dimension imbued with an intrinsic direction. According to Maudlin, this direction not only determines the direction of operation of laws but also underlies the other ??? of time’s arrows. Thus, in contrast to Armstrong’s account, Maudlin’s involves an intimate relation between laws and time and more generally with spatial- temporal structure since laws on his account reflect this structure. We will return to the relation between laws and time throughout our discussion.

Maudlin’s account is an improvement over Armstrong’s as an account of fundamental laws of physics. But it, like Armstrong’s, involves positing an entity over and above the events that laws are supposed to govern and a relation of governing that is supposed to explain these events, support counterfactuals and so on. This entity, like N(F,G), takes the place of God and His governance assumed in the 18th century view of laws. Armstrong’ and Maudlin’s accounts don’t presuppose theology but just because they don’t, they need to say more about the nature of laws and their relations to mundane events if we are to understand what laws are and how they govern. Although their metaphysics is coherent without God, the reason to mention the theological background is that it may give us reason to be skeptical of intuitions that are often invoked in support of governance accounts when we realize that these intuitions may depend on remnants of an 18th century concept.

Powers Accounts:

 The second kind of non-Humean account I want to discuss are so called “Powers Accounts.” These are in certain respects throwbacks to the Aristotelian view of science that the 17th century account based on mathematical laws replaced. Aristotelian science saw nature as composed of many different kinds of entities each with their own powers and capacities and the task of science to inventory and describe them.

During the 17th century, laws took the place of powers in scientific theories of motion. Some advocates of the law-based accounts that arose in the 17th century kept a diminished role for something like Aristotelian powers. For example, Newton apparently thought that matter possesses the capacity to follow the laws of motion and gravitation. This was proposed as a way of making sense of the governing metaphor since a governor requires a subject capable of obedience (Psillos). Contemporary advocates of powers accounts like Alexander Bird reject laws in favor of powers as the only source of motion. On this view, laws are regularities that follow from the behavior of powers. So, powers do the governing and laws record the resulting regularities. [[10]](#footnote-10)

 One of the problems with powers accounts of laws is that they like Armstrong’s universals are also out of tune with contemporary physics. Laws like those expressed by Schrödinger’s equation construe laws as relating the entire state of an isolated system at one time (or surface) with its state at other times while the powers account connects instantiations of powers with other instantiations of powers. Perhaps one could derive state relating laws from powers but that would require composition principles in addition to powers and these principles would be laws. Also, it is difficult to see how this would work for quantum mechanics where the quantum state of a system is not composed of the quantum states of parts.

 There are two further points to be made now about powers accounts. One is that if talk of powers is taken seriously then it involves the power of the state of a system at one time to produce the state of a system at subsequent times. This notion of production seems as mysterious as governing. Instead of a law making a G follow an F it is now in the power of F to make a G follow it. Second, like Maudlin’s account this seems to assume a metaphysically fundamental direction of time. F’s power is to bring about a G at a subsequent time. We can remove the presupposition of a primitive direction time by dropping talk of powers and just propose the view that the instantiation of a property at one time (or location) metaphysically necessitates the instantiation of properties at distinct times and locations. This makes the necessity more familiar if still mysterious. Laws are then the necessary truths that result. Note that on this view although laws are necessary truths since the properties they relate are not necessarily instantiated there is a sense in which lawful contingency is preserved. The resulting non-Humeanism is rather thin. In fact, it is so thin we will later see how even someone with Humean scruples can countenance it.

 Non-Humean accounts possess an epistemic feature that may seem troubling. It is that there can be two possible worlds that seem exactly alike and yet differ radically with respect to their laws. For example, on a governing account there can be two worlds in which particles move on exactly the same space-time trajectories except that in the first the particle motions are governed by Newtonian laws while in the second the trajectories are governed by different laws or no laws. On a powers account there can also be a world in which the particles move on the same trajectories but instantiate different powers. The alleged epistemological problem is that if all we can directly see are the particle trajectories then this seems to lead non-Humean accounts of laws down the rabbit hole of skepticism.

 Proponents of non-Humean accounts have a reply. They don’t claim to be able to “see” governing laws or “powers.” Their thought is that the best way of explaining what we do see involves appeal to non-Humean laws or powers. In fact, they claim that Humean laws are not capable of supporting explanations at all. If that is correct, then it is the Humean who has the epistemological problem since much of our knowledge is based on inference by explanation. The non-Humean line of argument is that since Humean laws can’t support explanations and non -Humean laws of both varieties do and since laws do support explanations a non-Humean account must be correct. Of course, this conclusion assumes that non-Humean laws really can explain. I will return to this argument after examining a Humean account of laws more closely.

Humean Accounts:

 Hume is known for inspiring the regularity account of causation according to which a type of event C causes a type of event E when there is a correlation between occurrences of events of these types that satisfies some further conditions, and these further conditions don’t involve necessary connections.[[11]](#footnote-11) Hume doesn’t say very much about the metaphysics of what we would consider fundamental laws even though he was doubtless familiar with Newtonian mechanics. Despite the lack of discussion by Hume the view that laws are correlations between types of events that satisfy further conditions that don’t involve necessary connections like those produced by governing and powers has come to be known as “Humean.” The problem for the Humean is specifying the additional conditions. This is a challenge since laws themselves seem to support some kind of necessity. So the problem for the Humean is showing how the kind of necessity involved in laws can be derived.

 The necessity involved in laws is that laws support counterfactuals. As Reichenbach pointed out, “There is nowhere in the universe a densely packed one meter in diameter sphere of uranium” expresses a law while a similar generalization with “gold” substituted for “uranium” does not. The first supports the counterfactual “if one were to try to produce a densely packed one meter in diameter sphere or uranium one would not succeed while the second doesn’t support a similar counterfactuals involving gold. The problem for Humeans is to specify those further conditions which enable a generalization to support a counterfactual without adverting to necessary connections, governing, powers, and the like and then to show that such generalizations deserve to be called “laws.” The most influential account that attempts this is David Lewis’ Best Systems Account (BSA).

The BSA specifies how laws supervene on possible worlds by identifying which regularities in the HM qualify as fundamental laws. Lewis didn’t write a single paper devoted to his account of laws but describes it in several places. One is

Take all deductive systems whose theorems are true. Some are simpler better systematized than others. Some are stronger, more informative than others. These virtues compete: An uninformative system can be very simple; an unsystematized compendium of miscellaneous information can be very informative. The best system is the one that strikes as good a balance as truth will allow between simplicity and strength. How good a balance that is will depend on how kind nature is. A regularity is a law iff it is a theorem of the best system. (1994a p.478)

 The idea guiding the best system account is that what makes a proposition lawful is its participation in a scintifically optimal systematization of the distribution of fundamental events. Lewis identifies a law determining systemization as aiming to achieve an optimal balance between informativeness and simplicity. He immediately recognizes that this requires a restriction on the language in which the propositions that are systematized are formulated. Without such a restriction the sentence VxSx where S is a predicate true of all and only actually existing objects counts as maximally informative and very simple and so would quality as an optimal systematization. Since VxSx entails every truth the disastrous consequence is that every truth is lawful. To avoid this Lewis proposes a restriction based on a central component of his metaphysics. According to him there are certain elite properties he calls “perfectly natural” which are the fundamental properties instantiated at each possible world and whose distribution in a space-time forms the supervenience base for all truths at that world. These properties are instantiated at points (or small regions) and the instantiation of one such property at a region doesn’t exclude or necessitate the instantiation of any other perfectly natural property at a distinct point (or non-overlapping region). Predicates that refer to perfectly natural properties will also be called “perfectly natural.” A perfectly natural property may be a magnitude, for example, mass or mass density which has a value. In this case the value at one point will exclude different values at the same point. But these are the only necessary connections among instantiations of perfectly natural properties. Lewis calls the distribution of the worlds’ perfectly natural properties its “Humean Mosaic.” (HM)[[12]](#footnote-12) . We can think of the HM as kind of field or overlapping fields. In Lewis Humean metaphysics all truths, including those involving laws, probabilities, counterfactuals, causation, explanation etc. supervene on the HM.

 Lewis proposes that the languages whose propositions are systematized by a world’s best system have only perfectly natural predicates in their extra mathematical vocabulary.[[13]](#footnote-13) This avoids the disaster since Sx is not a perfectly natural predicate and its definition in terms of perfectly natural predicate is enormously complicated. But it does so at the cost of building the best system account on the metaphysical posit that there is an elite class of fundamental categorical properties that don’t derive their elite status in virtue of appearing in laws but rather certain regularities derive their status of being lawful in part in virtue of involving perfectly natural properties. We will return later to consider just how costly this posit is.

 Having settled on the issue of the language whose truths are to be systematized the next issue is how candidate systems are evaluated. Lewis’ account is sketchy and inadequate. His measure of informativeness in terms of the size of the set of possible worlds excluded by a proposition is much too crude. Since it is plausible that there are infinitely many possible worlds it restricts comparisons of informativeness to sentences that are related by logical implication. Further, it counts logically equivalent sentences as equally informative even when one is much more complicated than the other. Also, it is not just quantity of information but how the information is organized that is important to systematization. A number of authors have argued that law determining systematizations should aim to organize information that is important to scientists in ways that are usable to them.[[14]](#footnote-14) For example, Ned Hall points out that a systematization that supports a distinction between states of system (or the universe) at a time and dynamical laws is much more useful to scientists than systems that don’t. A similar point holds for systems that permit the division of the world into approximately isolated systems whose evolutions are determined by the dynamical laws. Further, scientists have reason to obtain information not only what actually happens but also about what would happen under alternative circumstances in order to make decisions and extend knowledge. As we will see a system that includes dynamical laws that apply to isolated systems enables this.

Lewis’ proposal regarding simplicity is also crude. He suggests the length of sentences expressed in terms of perfectly natural predicates as a measure of simplicity. But this doesn’t have much to do with the way physicists evaluate simplicity when considering alternative theories. Physicists prize symmetries, numbers of fundamental kinds, numbers of constants and their relationships, and so on. There are further criteria that physicists look for fundamental theories to satisfy. For example, it is important that fundamental laws harmonize with space-time symmetries. Respecting space-time symmetries enables the formulation of simple conservation laws like the conservation of momentum and momentum.

Much more needs to be said about the criteria for evaluating a law determining best system law. But even if Lewis hasn’t satisfactorily characterized these criteria, we can see that he is gesturing at criteria that are employed within physics to evaluate theories and among these are criteria akin to what we could call “informativeness” and “simplicity.” Furthermore, we can see why satisfying these criteria is valuable and so why the discover of laws is valuable. For now, let’s take Lewis’ “informativeness” and “simplicity” as place holders for whatever criteria physicists employ and aim to balance in evaluating proposals for fundamental theories.

One worry about the BSA is what to say if these criteria when applied to our world do not determine a uniquely optimal systematization or if the best systematization for our world is so bad it shouldn’t be counted as law determining at all. Lewis suggests that in the first case laws are the generalizations common to all the optimal systems. A different response, which I prefer, would be to relativize the notion of law to a system. The second possibility is much more troubling. One response would be to give up on the concept of law just as Nancy Cartwright suggested once the theology behind governing is rejected. Another response, of course, is to give up the BSA. But I think such pessimism is unwarranted and premature. The history of science provides reason to believe that our world has optimal systematizations that are quite good and that if there is more than one, they will mostly agree on which generalizations are laws.

 Lewis’ BSA of laws is Humean in that it makes no use of fundamental necessary connections between distinct entities. The BSA assumes that fundamental properties are not powers and there is no room in the account for entities that govern. What the laws are at a world supervene on the distribution of perfectly natural properties at the world since they are entailed by axioms that optimally systematize it. A way of understanding the BSA is that promotes the systematizing aspect of the 17th century concept of laws into determining the laws while dispensing with the governing aspect. This doesn’t mean that one cannot say that classical mechanical laws understood as by the BSA “govern” the motions of the planets. But all this comes to for a Humean is that the motions of the planets conform to classical mechanical laws. Nor does it mean that the world has no powers as long as it is understood that fundamental properties are not powers and that true claims about powers supervene on the Humean mosaic.

 Is the BSA of laws adequate? The first point to note is that its criteria for determining which generalizations are lawful make no appeal to necessity, governing or powers so it qualifies as Humean. Second, it counts some but not all true generalizations as lawful, so it avoids the objection to simple regularity accounts. Third, it is clear that satisfying these criteria is desirable in a scientific theory. If physicist were to find the (or a) best system of the world they would think that it specifies the laws of the world. But it is too soon to declare the BSA successful. Before doing that a persuasive case needs to be made that being entailed by the world’s best systematization enables a proposition to perform the jobs required of lawful propositions.

Lewis’s BSA completely leaves out governing, necessary connections, and their ilk from the conditions that make a generalization lawful. Because of this it must be admitted up front that the BSA should not be thought of as an analysis of the concept of law of nature as it has been handed down from the 17th century and is currently unreflectingly used by scientists and analyzed by philosophers but more along the lines of a proposal for revising the old concept to produce a new ont that adequately accounts for the role of laws in science.

 Mistaking the BSA for an analysis is the trouble with objections that involve thought experiments which claim to show that there are possible worlds with the same Humean mosaics but with different laws. If the BSA were an analysis these objections would falsify it. A simple example of such a thought experiment considers a world that contains only a single particle moving uniformly. The generalizations expressed by Newton’s laws are true at this world, but the BSA would not count them as its laws. The best system for this world would just state that particles move uniformly. The argument is that since we can conceive that Newtonian laws are actually the laws of this world the BSA is wrong. It is easy enough to see that this argument for the possibility of such a world relies on a governance conception of laws. When one is conceiving that the Newtonian regularities being laws in the one particle world one is imaging them as governing the world. An advocate of the BSA grants that the ordinary concept of law has both governance and systematizing aspects but is recommending jettisoning the first aspect while maintaining the second. The revised concept excludes the possibility of Newtonian laws being the laws of the one particle world. A related point is that when physicists often consider worlds that are models of laws but whose best systematization doesn’t count them as laws. We can say that such worlds while not violating the laws of the original world undermine them as laws. The BSA can accommodate this practice by introcucing the idea of laws relative to a source world. In our example, Newton’s laws are laws of the one particle world consider laws relative to the Newtonian world.[[15]](#footnote-15)

 There are fancier thought experiments designed to show that laws don’t supervene on a worlds mosaic but they are all like this one so I won’t pursue this kind of objection further. The task of an account of laws isn’t to agree with intuitions but rather to show how laws according to that account are able to perform the jobs that scientists need laws to perform. Agreeing with philosophers’ intuitions is not one of those jobs.

 The two most important jobs involve the relations between laws and counterfactuals and laws and explanations. Regularities that are lawful typically support counterfactuals but regularities that are not lawful don’t. For example, the law that bodies traveling elliptical orbits that sweep out equal areas in equal times around the sun supports the counterfactual that if there were a planet orbiting between Jupiter and Uranus it would sweep out equal areas in equal times. But the mere regularity that all coins in my pocket are dimes does not support the counterfactual that if this quarter were in my pocket, it would be a dime. Related to this is the fact that a law is counterfactually stable under suppositions with which it is consistent. If L is a lawful regularity and B and -B are consistent with L then the counterfactuals B>L and -B>L are true.[[16]](#footnote-16) There is something about lawful regularities in contrast to mere regularities that enables them to say what would happen under merely possible circumstances and allows them to hold under counterfactual circumstances. The question is where does this ability come from? Non-Humeans attribute it to the necessity that laws provide regularities. It may seem, at first, that Humean BSA laws don’t have the resources to enable them to support counterfactuals or to enable counterfactual stability since they are mere regularities not backed by any necessity.

 In fact, the most well-known and developed account of counterfactuals is compatible with Humean accounts of laws. Further, given this account of counterfactuals the BSA explains why laws support counterfactuals and why they are counterfactually stable. The account is the Lewis-Stalnaker similarity account according to which A>B is true iff in all the worlds that are most similar to the actual world at which A is true B is also true.[[17]](#footnote-17) Lewis develops the account by characterizing similarity for relevant counterfactuals in terms of the size of the regions of worlds that match the actual world with respect to fundamental events and the size and extent with respect to fundamental laws.[[18]](#footnote-18) Similarity is determined by balancing these two factors where much more weight is given to worlds in which the size of the regions in which the actual laws fail, and the size of the failure is minimized.[[19]](#footnote-19) As far as this account is concerned the laws can be Humean or non-Humean.

 Still, the question arises as to what it is about laws that makes them so important in determining similarity involved in evaluating counterfactuals. In a very interesting paper Chris Dorst argues that the conditions that according to the BSA make a regularity a law provide an answer.[[20]](#footnote-20) Dorst points out that the best system for a world like ours yields dynamical laws that enable us to use counterfactual reasoning to extend our knowledge of the actual world if we treat laws as very important in evaluating counterfactual similarity. This is due to the fact that our world organizing information in terms of dynamical laws is optimal. For example, to figure out where a meteor that hits the moon at a particular place was a day prior one considers alternative hypotheses of the form “if the meteor had been at such and such a place a day earlier it would have landed at this place today. Evaluating these counterfactuals requires keeping the actual laws fixed. Similarly, the counterfactuals we use in deliberation involve considering what would happen were we to make alternative decisions. This also requires holding the actual laws constant when evaluating what happens in worlds similar to the actual world. Of course, what enables us to extend our knowledge of the actual world by counterfactual reasoning is that the laws are dynamical and can be applied to local circumstances. Non-Humean laws like this would work as well. But it is this fact that accounts for the importance of laws in evaluating counterfactual similarity. That the laws govern or are the result of the operation of powers is irrelevant. Further, Humeans have an account of why it is that we are interested in systematizing the world so that there is a division between laws and initial conditions.

 The previous discussion shows that BSA laws do just as well, maybe better, than non-Humean laws with respect to supporting counterfactuals and counterfactual resilience. The more serious problem concerns the role of laws in explanations. It has been claimed that while non-Humean laws can perform this role Humean laws being mere regularities cannot. An argument that is claimed to demonstrate this is clearly and forcefully stated by Maudlin as follows:

If one is a Humean, then the Humean Mosaic itself appears to admit of no further explanation. Since it is the ontological bedrock in terms of which all other existent things are to be explicated, none of these further things can really account for the structure of the Mosaic itself. This complaint has been
long voiced, commonly as an objection to any Humean account of laws. If the laws are nothing but generic features of the Human Mosaic, then there is a sense in which one cannot appeal to those very laws to explain the particular
features of the Mosaic itself: the laws are what they are in virtue of the Mosaic rather than vice versa (Maudlin 2007, p. 172).

The gist of the argument is that on a Humean account the Humean mosaic explains the laws. But since laws are supposed to explain their instances and these are included in the Humean mosaic we are led to the conclusion that the Humean mosaic explains part of itself. But this results in circularity, so something has gone wrong. Another way to put it is that if Humean laws explain events in the mosaic then these events being part of the mosaic would be part of the explanation of themselves. One feels the force of this objection if one thinks that the mosaic in some sense produces the law as Humeans seem to hold and then thinks of laws as explaining regularities by producing them. In this case the Humean mosaic would be producing (explaining) itself.

 Loewer (2012)responded to the circularity objection by distinguishing scientific explanation from metaphysical explanation. According to him Humean laws *scientifically explain* events by not by producing regularities but by unifying them by exhibiting the regularities that subsume them. That a regularity is a law is *metaphysically explained* by its being entailed by the best systematization of the Humean mosaic. As Elizabeth Miller (2015) points out Humeans needn’t hold that the HM “produces” the laws even it is true that the fact that the HM is a certain way explains why certain regularities are laws. In fact, on the BSA the HM doesn’t produce the laws but rather the best system is just a partial description of the HM. So for a Humean the mosaic doesn’t produce the laws and the laws don’t produce the mosaic.[[21]](#footnote-21) Loewer claims that these observations remove the threat of circularity since nothing metaphysically explains itself and nothing scientifically explains itself. Instead, the HM metaphysically explains the law and the law scientifically explains events in the HM by unifying them.

 Marc Lange (2013) has replied to Loewer’s response to the circularity objection by putting forward a transitivity principle that he thinks connects scientific and metaphysical explanation and which shows that Humeanism implies that the Humean mosaic scientifically explain a part of itself. If this were correct, then the problem would reemerge. The principle is

If E scientifically explains [or helps to scientifically explain] F and D grounds [or helps to ground] E, then D scientifically explains [or helps to scientifically explain] F.

That is, when E helps to scientifically explain F, then that explaining is also being done by whatever D makes E the case. If D is what it is in virtue of which E holds, then D plays whatever roles in scientific explanations E is playing.

Lange provides some examples that conform to his transitivity principle. For example, increasing the temperature of a gas in a balloon scientifically explains the balloon expanding, the increase in motions of the molecules in the case metaphysically explains why its temperature increases and it seems also to scientifically explains why the expanding of the balloon. Hicks and van Elswyck (2014) disambiguate Lange’s transitivity principle and provide convincing counterexamples to the version that is required by Lange’s argument. For example, the presence of a lion in a certain region may scientifically explain the number of prey animal in that region but while the locations and motions of a few molecules that partly compose the lion may help to metaphysically explain the presence of the lion, they don’t help to scientifically explain the number of prey animals. Had these molecules been elsewhere the number of prey animals would have been the same. For Lange’s argument based on his transitivity principle to have force he it would need to be exceptionless or at least to that it applies to the case explanation by Humean laws. He hasn’t established this and so it is not clear that the principle applies in this case at all.

 In any case, it is not difficult to see what is going on in anti-Humean arguments that that Humean laws are incapable of supporting explanations. On anti-Humean accounts laws explain a regularity by being producing it or resulting from the activities of powers that produce it. A governing law takes the antecedent and evolves it into the consequent thus making the corresponding regularity obtain. On powers accounts the antecedent power produces the consequent making the regularity obtain. On both accounts a law is distinct from but sufficient for its associated regularity. Although contemporary versions of these accounts of laws have dispensed with theological assumptions the idea that laws explain regularities by producing them may be a remnant of the concept’s theological origin. In any case, Humean laws cannot explain in this way.

 If Humean laws don’t explain by governing or by producing, how do they explain? The answer is that they explain by systematizing and unifying. A system unifies disparate phenomena by showing how statements describing these phenomena are derivable from a few axioms that exhibit connections among them. For example, classical mechanics unifies the motions of pendula and cannon balls by showing how their trajectories derive from Newton’s dynamical and gravitational laws. It similarly unifies terrestrial and celestial motions. Showing that and how these phenomena follow the same laws explains them. The system also unifies counterfactuals since it specifies what happens were initial conditions to be different. For example, the fact that a rocket escapes the earth’s gravitation field is explained by showing that its velocity exceeded escape velocity and that if its velocity had been appreciably lower it would have fallen back to earth. The fact that a law unifies events in the mosaic and that it is the entire mosaic that makes it a law doesn’t mean that the entire mosaic unifies part of itself. Lange’s transitivity principle fails if laws are understood as explaining by unifying.

 Of course, laws are involved in explanations in other ways than by unifying. Causes explain their effects and laws underlie causation. There are Humean accounts of causation in terms of counterfactuals and in terms of probabilities. If these accounts can be made to work, then the objection that Humean laws cannot play the role of laws in explanation fails.

 Here is where we have gotten to so far. The idea that a primary goal of physics is the discover of laws of nature and that laws are the engines of scientific explanation emerged during the 17th century. At that time laws of nature were conceived of as principles that describe how God governs the motions of matter or as the instruments He employs to enforce those principles. The principles were thought to exhibit characteristics worthy of the Deity; they are mathematical, simple, elegant, comprehensive, eternal, deterministic, and so on. Over time the theological presuppositions of this view of laws fell away but the view that laws form a system of principles that satisfy these characteristics and also govern persisted. Contemporary metaphysics of laws has divided into two camps Humean BSA and non-Humean governing and powers with the first rejecting the governing aspect and accepting the systematizing aspect and non-Humeans elevating the governing aspect while de-emphasizing the systematizing aspect. Both approaches can be developed into coherent metaphysical accounts of laws. However, we have seen that appealing to governing and or powers involves metaphysical commitments that while they replace the role of God seem to work in ways that are just as mysterious. Further, many of the objections to Humean accounts rely on remnants of the concept of law’s theological origin and the scientific work that laws actually perform rely on the systematizing aspect.

II. Chance

1. Of course for Descartes and some of his contemporaries the exception was human beings whose motions are due to the activities of their minds. [↑](#footnote-ref-1)
2. See Walter Ott who shows how both systematizing and governing are central to Berkeley’s conception of law of nature. [↑](#footnote-ref-2)
3. Laplace famously asserted that determinism is true and when asked by Napoleon what role the Creator has in his system replied that he has no need for that hypothesis. [↑](#footnote-ref-3)
4. John Foster, The Divine Lawmaker: Lectures on Induction, Laws of Nature, and the Existence of God, Oxford University Press, 2004,  [↑](#footnote-ref-4)
5. Nancy Carwright *How the Laws of Physics Lie* Oxford (1983) [↑](#footnote-ref-5)
6. The fact that the frequency of the number of male births to female births per year is constant even though it is impossible to predict the gender of the next birth was taken to be evidence for God’s existence. [↑](#footnote-ref-6)
7. According too Hacking this story is mythology (Hacking Emergence of Probability ) [↑](#footnote-ref-7)
8. Carl Hoefer is an exception. He develops a Humean account of chance while maintain a non-Humean account of laws. [↑](#footnote-ref-8)
9. Universals are abstract entities that determine properties which Lewis understands as sets of possible individuals. [↑](#footnote-ref-9)
10. One way to develop this idea is that there are a limited number of fundamental physical entities and properties upon whose powers the powers and lawful regularities of non-fundamental reality depends. Nancy Cartwright is also a proponent of fundamental powers, but she rejects that they are limited to fundamental properties and holds hat higher level properties may have their own powers and capacities that are not derivable from those of fundamental powers She also holds that the lawful regularities powers produce may only hold *ceteris paribus*. We will return to her views later. [↑](#footnote-ref-10)
11. It may be, as Galen Strawson suggests, that Hume actually held that causation involved the obtaining of a necessary connection between C events and E events but that our knowledge is limited to the correlation. My interest is not in what Hume really thought but the views he inspired. [↑](#footnote-ref-11)
12. If the only perfectly natural relations that are instantiated at a world are geometrical relations, then Lewis says the world satisfies a condition called “Humean Supervenience.” He speculates that the actual world may satisfy this condition but worries that it may be violated by quantum mechanics. For a discussion see Loewer (1996) [↑](#footnote-ref-12)
13. We will see later that he relaxes this requirement to allow probability relations to appear in extra athematical vocabulary and we will examine a proposal for relaxing it further. [↑](#footnote-ref-13)
14. See for example Hicks, Loew and Jaag, Dorst [↑](#footnote-ref-14)
15. See Halpin (2003) where this approach is developed. [↑](#footnote-ref-15)
16. Although L would still have been true if might not have been a lawful regularity. [↑](#footnote-ref-16)
17. Stalnaker and Lewis’ accounts differ in certain respects since Stalnaker requires a uniquely most similar world and Lewis’ account is a bit more complicated than my version here since he allows chains of similarity without a most similar world. . [↑](#footnote-ref-17)
18. The exact details of Lewis’ account will be discussed in part II of this book. As will shown his particular account is defective but that fact doesn’t affect the point here that it is compatible with a Humean understanding of laws. The same holds for the improved account developed in part II. [↑](#footnote-ref-18)
19. . For example, “If the meteor that impacted off the coast of the Yucatan had missed the earth dinosaurs would have continued to live for at least another 20 million years” is true iff in the most similar worlds to the actual world in which the meteor misses the earth the dinosaurs continue to live for another million years”. Lewis thinks that his account of similarity has the result that the most similar world to the actual world in which the antecedent is true are worlds that exactly match the actual world until a short time before the actual time of impact when the meteor swerves so as not to hit the earth. If the fundamental laws are deterministic this will require a small violation of the fundamental laws. But after that violation the actual laws obtain. [↑](#footnote-ref-19)
20. Dorst Why Do Laws Support Counterfactuals” [↑](#footnote-ref-20)
21. Miller, Elizabeth 2015 [↑](#footnote-ref-21)