The Package Deal Account of Laws and Properties (PDA)**

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Abstract:

This paper develops an account of the metaphysics of fundamental laws I call "the Package Deal Account (PDA)" that is a descendent of Lewis' BSA but differs from it in a number of significant ways. It also rejects some elements of the metaphysics in which Lewis develops his BSA. First, Lewis proposed a metaphysical thesis about fundamental properties he calls "Humean Supervenience" (HS) according to which all fundamental properties are instantiated by points or point sized individuals and the only fundamental relations are geometrical spatial and temporal relations between these. While the BSA does not require HS Lewis seems to hope that it is true. In contrast, the PDA is not committed to HS or even to the fundamental arena in which fundamental properties are instantiated possessing geometrical structure and thus is able to accommodate relations and structures found in contemporary physics that apparently conflict with HS. Second, although Lewis' BSA doesn't require HS his Humeanism does require that fundamental properties are categorical. In contrast, the PDA allows for the possibility that fundamental properties are individuated in terms of laws and so are not categorical. Third, the PDA expands and develops the criteria for what counts in favor of a candidate system with more attention to the criteria employed by physicists in evaluating proposed theories. Fourth and most importantly, unlike Lewis' BSA, the PDA does not presuppose metaphysically primitive elite properties/quantities that Lewis calls "perfectly natural" properties/quantities or presuppose a metaphysically preferred language whose terms denote such properties/quantities. It replaces Lewis' account with an account on which natural properties are not metaphysically prior to the laws but are elements of a package that includes a fundamental arena that plays the role of space-time as well as fundamental laws and properties. By doing so it responds to some epistemological and metaphysical issues that have been raised regarding natural properties and their role in the BSA. In sum, the PDA goes further in explicating the notion of laws in terms of the aims and practices of science especially fundamental physics rather than in terms of prior metaphysics. I begin by reviewing Lewis' account of perfectly natural properties and his Humean BSA of laws.

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I.   Introduction

One of the primary goals of the sciences is the discovery of the laws that explain natural

phenomena. There is a tradition in physics that originated in the 17th century especially with the

success of Newtonian mechanics according to which physics aims to discover the world's

fundamental ontology and quantities and a system of laws that describe its behavior. Proposals

for fundamental ontologies and laws have included Newton's laws of classical particle

mechanics and gravitation, Maxwell's electromagnetic field equations, Schrödinger's law, and

the equations of General Relativity. The dream of some physicists is of a final theory – what

Steven Weinberg calls the Theory of Everything TOE-that specifies the world's fundamental

ontology and unifies quantum mechanics and general relativity and thus specifies laws that

cover all physical phenomena while satisfying the criteria that physicists have come to expect of

fundamental theories.

While it is the job of physics to find fundamental laws, it is the job of philosophy to say what

fundamental laws are. Contemporary philosophy is dominated by two approaches to answering

this metaphysical question that I will call Necessitarian and Humean accounts.[1] Necessitarian

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[1] "Necessitarian" because these accounts all hold that there are fundamental necessary connections in nature and that laws either account for them or are consequences of them. Governing accounts originated in the 17th century with the idea that laws are the principles by which God governs the motions of bodies (see Harrison). There are also Powers and dispositionalist accounts locate necessary connections in fundamental dispositions and powers of certain properties and laws as due to their activities. These accounts are developments of Aristotelian and medieval accounts of natural necessity. Cartwright (1999), Mumford (1998).

accounts hold that reality includes necessary connections in virtue of which laws are able to

play their roles in explanation, confirmation, counterfactuals and causation. Humean accounts

claim that laws don't require fundamental necessary connections.

There are two main varieties of necessitarian accounts- i) governing views and ii)

powers views employing different kinds of necessity.[2] While talk of governing echoes the

theological birth in the 17th century of the concept of scientific law few of its philosophical

defenders make an overt appeal to theology to explicate it.[3] Rather, they understand laws to be

features of reality over and above occurrent events that in some way necessitate or constrain

them.[4] Some go a bit further saying that a dynamical law governs by taking the state of a

system (or the state of the entire universe) at a time (or on a Cauchy surface) and evolving it to

subsequent states thus forging necessary connections between the earlier and later states.[5] On

governing accounts laws are contingent so the kind of necessity they bestow is weaker than

metaphysical necessity.

In contrast on powers accounts laws involve metaphysically necessary connections.[6] These

accounts hold that fundamental properties are or necessarily possess powers whose

instantiations produce necessary connections among events and that laws are regularities that

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[2] A third view on which laws involve necessary connections is Marc Lange's counterfactual account on which
lawful propositions are those that are stable under certain conditions. Lange 2009.
[3] Two philosophers who do make the connection between theology and governing explicit but for different reasons
are John Foster (2005) and Nancy Cartwright (2004). Foster in *The Divine Law Maker* argues that God's will is
required to make sense of the governing role of laws and Cartwright in "No God No Laws" appeals the connection
between laws and theology in her argument that there are no laws of nature and for a return to a more Aristotelian
account of science.
[4] This type of account of laws was developed by Armstrong, Dretske and Tooley in the 1980s
[5] Tim Maudlin (2007) proposes an account along these lines. The account also forges a connection between accounts
of laws and accounts of the nature of time. This connection is discussed in Loewer (2012).
[6] On powers accounts laws lawful regularities are metaphysically necessary but whether or not the properties
connected by a law are instantiated is contingent.

hold in virtue of the exercise of these powers. Since these regularities hold in virtue of the natures of the properties they connect they are metaphysically necessary. Some necessitarian views are mixtures of governing and powers accounts.

Humean accounts, in contrast, hold that laws do not produce or hold in virtue of necessary connections and more generally that there are no *fundamental* necessary connections in nature. Accordingly, laws don't govern, and fundamental properties are not powers. On Humean accounts the instantiation of a fundamental property/quantity at one space-time location has no necessary connections with instantiation of properties at non-overlapping locations.[7] Such properties are said to be "categorical." For example, colors seem to be non-fundamental categorical properties. The region around a red object can be any color or no color at all. Hume rejected necessary connections as features of reality because given his accounts of ideas and knowledge he couldn't see how we could form ideas of them and even if we could how we could know about them.[8] Most contemporary Humeans don't agree with Hume's theory of ideas or his epistemology. But they agree with Hume that fundamental necessary connections between distinct entities are metaphysically and epistemologically mysterious and not required by an account of the metaphysics of law.[9] Instead, Humean accounts understand laws to be truths that express scientifically significant regularities that are able to play their

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[7] But properties/quantities instantiated in the same or overlapping locations may be necessarily connected. For example, having a mass of 5 grams necessarily excludes having a mass of 6 grams.

[8] There is controversy concerning Hume's view. The standard interpretation is that Hume held that since we have no impression of necessary connections between events we cannot form concepts of them and concludes that they don't exist. Recently some reject this and instead understand Hume as claiming only that we can't know about them e.g. Strawson (2011).

[9] This is not to say that Humeans must eschew notions of metaphysical and nomological necessity that can be explained in terms that don't presuppose them e.g. Lewis sees nomologically necessary connections as encapsulating certain patterns among events while others e.g. Blackburn see them as projections by us onto the pattern of events.

roles in scientific explanations, causation, induction and so on without any reliance on powers or governing.[10] The most prominent contemporary Humean account of laws is David Lewis' Humean Best System Account (BSA).[11]

In this paper I will describe an account of the metaphysics of fundamental laws I call "the Package Deal Account (PDA)" that is a descendent of Lewis' BSA but differs from it in a number of significant ways. It also rejects some elements of the metaphysics in which Lewis develops his BSA. Here is a preview of some these ways: First, Lewis proposed a metaphysical thesis about fundamental properties he calls "Humean Supervenience" (HS) according to which all fundamental properties are instantiated by points or point sized individuals and the only fundamental relations are geometrical spatial and temporal relations between these. While the BSA does not require HS Lewis seems to think that may well be true. In contrast, the PDA is not committed to HS or even to the fundamental arena in which fundamental properties are instantiated possessing geometrical structure and thus is able to accommodate relations and structures found in contemporary physics that apparently conflict with HS. Second, although Lewis' BSA doesn't require HS his Humeanism does require that fundamental properties are categorical. In contrast, the PDA allows for the possibility that fundamental properties are individuated in terms of laws and so are not categorical. Thus it permits necessary connections but not in a way that should trouble Humean scruples. Third, the PDA expands and develops the criteria for what counts in favor of a candidate system with more attention to the criteria

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[10] Among recent proponents of Humean views are David Lewis, John Earman (1984), Mike Hicks (2018) Stathis Psillos, (2014) and Barry Loewer (1996, 2007).

[11] Lewis first discusses the account in Lewis (1973) and elaborates in Lewis (1986). He attributes the basic idea of the BSA to Mill and Ramsey. The BSA is further developed and defended in Loewer (1996) and Beebee (2000).

employed by physicists in evaluating proposed theories. Fourth and most importantly, unlike Lewis' BSA, the PDA does not presuppose metaphysically primitive elite properties/quantities that Lewis calls "perfectly natural" properties/quantities or presuppose a metaphysically preferred language whose terms denote such properties/quantities. It replaces Lewis' account with an account on which natural properties are not metaphysically prior to the laws but are elements of a package that includes a fundamental arena that plays the role of space-time as well as fundamental laws and properties. By doing so it responds to some epistemological and metaphysical issues that have been raised regarding natural properties and their role in the BSA. In sum, the PDA goes further in explicating the notion of laws in terms of the aims and practices of science especially fundamental physics rather than in terms of prior metaphysics. I begin by reviewing Lewis' account of perfectly natural properties and his Humean BSA of laws.

II. David Lewis' Humean BSA

In "New Work for a Theory of Universals" Lewis announced that David Armstrong persuaded him that not all properties are equal. He says that reality also includes a distinction between perfectly natural properties/relations and the rest.

> "Formerly I had been persuaded by Goodman and others that all properties were equal: it was hopeless to try to distinguish 'natural' properties from gruesomely gerrymandered, disjunctive properties.
> Eventually I was persuaded, largely by D.M. Armstrong, that the distinction I had rejected was so commonsensical and so serviceable -indeed, was so often indispensable - that it was foolish to try to get on without it." (Lewis 1999 pp.1,2)

While properties in general are abundant perfectly natural properties are sparse and special. They constitute an *elite* minority.   Lewis says that the distinction between the perfectly natural properties and the others is either itself primitive or that it may be explained in terms of primitive notions of *universals* or *similarity*[12].   His reasons for positing perfect naturalness are, he says, that it is commonsensical, serviceable, and explanatorily indispensable. Lewis employs it in his accounts of laws, causation, intrinsic vs. extrinsic, similarity, projectability, metaphysical necessity and possibility, reference, and other philosophically important concepts. His reason for taking it as a primitive is that he cannot see how to analyze it only in terms of actual truths or even in terms of truths at all concrete possible worlds. Lewis writes

> Many philosophers are skeptical about the distinction between natural and gruesome properties. They think it illegitimate, unless it can somehow be drawn in terms that do not presuppose it. It is impossible to do that, I think, because we presuppose it constantly. Shall we say that natural properties are the ones that figure in laws of nature? - Not if we are going to use naturalness of properties when we draw the line between laws of nature and accidental regularities. Shall we say that they are the ones that figure in the content of thought? - Not if we are going to say that avoidance of gratuitous gruesomeness is part of what constitutes the correctness of an ascription of content. Shall we say that they are the ones whose instances are united by resemblance? - Not if we are going to say that resemblance is the sharing of natural properties. Unless we are prepared to forgo some of the uses of the distinction between natural and unnatural properties, we shall have no easy way to define it without circularity. That is no reason to reject the distinction. Rather, that is a reason to accept it - as primitive, if need be." (Lewis 1986 p.5)

It is important to emphasize that Lewis thinks of naturalness as a metaphysical presupposition required by science. Whether or not a property/quantity is perfectly natural is a matter of metaphysics not physics. This is not to say that naturalness is unrelated to science and in particular to physics. Lewis thinks that because fundamental laws link perfectly natural properties physics is our best guide to them. On the assumption that physics has been doing its job well he gives as examples of good candidates for natural properties *charge, mass,* and *spin.* Metaphorically speaking, when God created the plurality of worlds He decided which

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[12] Lewis also thinks that there are degrees of naturalness. It may be that the degree of naturalness of a property can be defined in terms of perfect naturalness and complexity, but I don't know of any account that works. In any case, only perfectly natural properties figure in my discussion.

properties/quantities are perfectly natural. Each of these worlds consists of a space-time throughout which fundamental natural properties are distributed. It is a job for physics to find the perfectly natural properties instantiated in our world by finding its laws.

Lewis says that perfectly natural properties are intrinsic to the individuals that instantiate them and are categorical. Categorical properties contrast with dispositional properties and powers which are individuated wholly or partly in terms of their nomological and causal connections. Since no individual can possess two distinct values for its mass at the same time it is best to think of perfectly natural properties as magnitudes that can take on various values.[13] The assumption that all perfectly natural properties are categorical enables Lewis to formulate a principle of recombination in his account of possible worlds. The principle says that given a space-time every mathematically possible way of combining instantiations of perfectly natural properties to fill the space-time is a possible world and every possible world is such a combination.[14] It is due to the way that perfectly natural properties compose possible worlds that they earn the title of "metaphysical joints of reality." (Lewis 1986 p.60)

According to Lewis' Humeanism all contingent truths at a world W including truths about laws, causation, probability, nomological necessity etc. supervene on the distribution of perfectly natural properties in W. He calls the distribution of perfectly natural properties and relations throughout space time "the Humean mosaic" (HM). In other words, possible worlds that completely agree on their HMs also agree with respect to their laws, counterfactuals, casual connections, chances and so on. Lewis' program for establishing the supervenience is to propose and argue for account of laws, counterfactuals, and so on that are characterized in terms of the space-time distribution of perfectly natural properties. In this paper I will be

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[13] Because no individual can have distinct values of mass, charge, etc. Ned Hall suggest calling them "magnitudes". Hall (2020). But I will continue to refer to them as "natural properties" with the understanding that a natural property may have many values.
[14] In Lewisian metaphysics individuals are world bound, i.e. no individual exists at more than one point. Points in a world's space-time are fundamental individuals and certain regions in a space-time may also be fundamental although Lewis doesn't say what makes a region of points a fundamental individual.

concerned mostly with the supervenience of laws on the distribution of fundamental properties and relations.

Lewis also tentatively propose a metaphysical view he calls "Humean Supervenience (HS)". HS adds to his Humeanism the further condition that the perfectly natural properties instantiated in the actual world are instantiated only at points or by point sized entities and that the only instantiated perfectly natural relations are geometrical, e.g. temporal and spatial distances between points. He seems to think that HS is the metaphysics of classical mechanics, electromagnetism and relativity theory although it may be threatened by quantum mechanics. I return to this worry below.

> The BSA specifies how laws supervene on possible worlds as follows:

> 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. (1994 p.478)

Laws involving objective probabilities enter the picture by letting deductive systems include sentences that specify the probabilities of events.

> Consider deductive systems that pertain not only to what happens in history, but also to what the chances are of various outcomes in various situations - for instance the decay probabilities for atoms of various isotopes. Require these systems to be true in what they say about history....Require also that these systems aren't in the business of guessing the outcomes of what, by their own lights, are chance events; they never say that A without also saying that A never had any chance of not coming about. (1999 p.480)

Lewis' proposal is that probabilities are not themselves items that are part of the fundamental Humean mosaic but are introduced along with laws to aid in systematizing the mosaic.[15] While he thinks his account applies only to dynamical probabilistic laws it can be extended to include laws that specify probabilities over initial conditions like those found in statistical mechanics and certain versions of quantum mechanics.[16] I have argued elsewhere that all objective probabilities including those that appear in the special sciences, gambling, metrology and so on are grounded in statistical mechanical probabilities and thus the BSA provides a metaphysical account of all objective probabilities.[17]

The idea underlying the BSA is that certain true propositions are laws in virtue of their being entailed by the best systematization of the Humean mosaic.[18] According to Lewis the best systematization is the one that is true and that optimally balances simplicity and informativeness. The account is Humean since its laws don't govern or involve fundamental necessary connections and they supervene on the HM. They are propositions that describe regularities and patterns exhibited by fundamental properties. On the Humean view it is in virtue of the systematizing role of law propositions not in virtue of governing that they are capable of explaining, supporting counterfactuals and grounding causation. Proponents of governing and powers views may also think that as a matter of fact the lawful truths of our world can be systematized and that looking for a systematization is a good way to look for laws.

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[15] For an account of how probabilistic laws systematize by conveying information in terms of degrees of belief see Loewer 2004.

[16] As described for example in Albert (2000) and Loewer (2020)

[17] See Loewer (2000) and (2020).

[18] Lewis doesn't say exactly what further features a proposition entailed by the best system are needed to earn the title 'law' although he seems to think that laws must be generalizations and dynamical. I don't think this is right since there may restrictions on initial conditions and propositions like symmetry principles that may be entailed by the best system and play the role of laws and so should be considered to be laws.

But they do not think that this is what makes a proposition express a law. In contrast, on the Humean view it is constitutive of being a law that it is a component of the best systematization.

The reason Lewis appeals to simplicity and informativeness in characterizing the law determining best system is that these are among the criteria that have been employed in the history of physics to evaluate proposals for law specifying fundamental theories. In general, the more a theory says about its subject matter the better and the simpler it says it the better when complexity adds no predictive or explanatory value. Lewis suggests that the informativeness of a theory is measured in terms of possibilities excluded and seems to think of simplicity syntactically. But he admits that his accounts of simplicity and informativeness are not adequate and require further elaboration. They are at best gestures in the direction of the criteria appealed to by physicists in evaluating proposals for fundamental theories. Exactly what the criteria should be for evaluating candidate systems on the BSA requires further discussion which I leave for later in this paper.

Lewis' formulation of the BSA relies essentially on his distinction between perfectly natural properties and the rest. He points out that without a preferred language in which to formulate candidates for the best system the BSA can be trivialized in the following way. Let Fx be a predicate that is true of all and only individuals that exist at the actual world and suppose, with Lewis, that individuals are world bound. VxFx is counted as maximally informative since it is true only at the actual world excluding all the rest. It is also very simple syntactically. Consequently, it wins the competition for the world's best theory. But VxFx entails all truths and so renders all generalizations laws thus collapsing the distinction between lawful and accidental regularities. The remedy according to Lewis is to restrict the language in which

candidates for best theory of a world are formulated to a preferred language whose basic non-logical and non-mathematical predicates refer only to perfectly natural properties. Fx clearly is not such a predicate so the problem is averted. Lewis' proposal is attractive since it is plausible that the law determining systems are formulated in a language whose basic terms refer to the world's metaphysical joints. However, I will argue later that Lewis' reliance on perfectly natural properties in his BSA gives rise to serious problems.[19]

Lewis' BSA has many virtues. Chief among these are that it dispenses with the obscure metaphor of governing and with mysterious fundamental powers and necessary connections. Further, by treating laws and probabilities together it clarifies the concept of probability without appeal to mysterious propensities and it connects probabilities with frequencies and so provides an explanation of why probabilities should guide rational belief.[20] It forms the basis of Humean accounts of counterfactuals, causation, dispositions, explanation, and special science laws, and thus provides the framework for a Humean metaphysics of science. Another important virtue is that by building the aim of theoretical physics to find a best systematization into the account of laws it begins to answer to the question of how physics finds fundamental laws.

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[19] Lewis' proposal counts propositions as laws that are generally not regarded to be such. While gruesome predicates don't refer to perfectly natural properties generalizations composed of them e.g. "all emerubies are gred" may still be entailed by the best theory. This doesn't seem to me to be a serious problem since such generalizations are nomologically necessary and further conditions (e.g. predicates refer to properties that are near natural) can be added to weed out generalizations like "all emerubies are gred" which would not be considered to express laws.

[20] Lewis shows how to extend the account to probabilistic laws and proposes a principle for how probabilities should guide rational belief in (1994). His approach is modified and extended in Loewer (2004) and Hoefer (2020). Lewis says that he can "see dimly but well enough" why Humean probabilities should guide credence. Loewer and Hoefer provide arguments for this.

Opponents of Lewis' BSA claim that its virtues, whatever they may be, are outweighed by its vices. In particular, proponents of necessitarian accounts of laws argue that Lewis' Humean BSA delivers imposters at best. It has been claimed that the BSA violates anti supervenience intuitions to the effect that worlds that match with respect to their distribution of properties may differ in their laws and more damagingly that it fails to account for the roles of laws in explanation, induction, and grounding causation.[21] To a non-Humean the regularities the world exhibits appear to be enormous coincidences.[22] I think all these alleged objections can all be handled by the BSA and I and others have argued so elsewhere.[23] Here I want to discuss problems caused for Lewis' BSA due to his building the account within the framework of HS and perfectly natural properties. I will focus on two related problems. One is the more familiar one that HS and more generally perfectly natural properties, are not a suitable metaphysics for some theories that are taken seriously in contemporary physics. The other problem, which was first raised by Bas van Frassen, is that by relying on perfectly natural properties the BSA not only builds a controversial metaphysical posit into the account but also opens the possibility of a mismatch between what it says the laws are and what ideal science if fully informed would say what laws there are. Further, it possibly severs the connection between laws and the aims of theoretical physics so as to make it puzzling why physicists value laws. Addressing these issues results in a version of the BSA that is not committed to HS, to perfectly natural properties or even to the non-existence of fundamental necessary connections but still endorses the idea

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[21] Armstrong (1983), Maudlin (2007), Foster (2004) Lange (2009)

[22] This complaint is made by many non-Humeans e.g. Foster (2004). It is especially forcefully presented by Lazarovici (ms.) Of course, to a Humean this complaint appears question begging.

[23] Loewer 1996,2012, 2020 Beebee (2000), Hicks (2014), Miller (2015)

that laws are not regularity enforces but that they are components of a scientifically optimal system. I call this revision of the BSA the "Package Deal Account" or the PDA.[24]

III. Problems with Humean Supervenience and Perfectly Natural Properties:

Lewis says that it is the task of fundamental physics to locate the perfectly natural properties and relations that are instantiated in the actual world and systematize the space-time-distribution of their instances. While which perfectly natural properties are instantiated at the actual world their distribution are contingent which properties are perfectly natural is a matter of metaphysical necessity.

As was previously mentioned Lewis tentatively proposes that at the actual world all the perfectly natural properties are instantiated at points and the only perfectly natural relations are metrical. His examples of perfectly natural properties are mass and charge and metrical relations between points in a three plus one-dimensional Euclidian space time. The trouble for HS is that even if one were to grant that mass and charge are categorical properties (which is not obvious) contemporary physics apparently posits fundamental individuals, properties and relations that are not compatible with HS or even with Lewis' form of Humeanism. Quantum theory, the standard model of elementary particles and proposals for quantum gravity posit individuals that are not point size, fundamental properties that are not instantiated at points or point sized individuals, vector valued quantities, relations beyond geometrical relations, spaces with more than 4-dimensions and even in which space-time with geometrical relations is not

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[24] The initial formulation of the PDA is in Loewer (2007). The account of the PDA developed in this paper goes considerably beyond its initial formulation. Callender and Cohen (2009) develop a version of the BSA for special science laws that also doesn't rely on Lewis' perfectly natural properties.

the fundamental arena. [25] It is arguable that quantum field theory and even classical field theory and general relativity posit fundamental quantities that are not categorical but whose instantiations involve nomological connections with other quantities.[26] Further, some laws take the form of symmetry principles that seem to individuate properties/quantities in terms of necessary connections between their instantiations in distinct space-time regions. All these call into question not only HS but the entire ontological basis on which Lewis' Humean BSA depends especially its dependence on perfectly natural properties. Lewis says he wouldn't grieve if it turns out that HS is false of the actual world. He worries that quantum mechanics threatens HS. He says his reason for defending HS is that even if it is false his defense of it "can doubtlessly be adapted to whatever better supervenience thesis may emerge from better physics"[27] But his Humeanism and its supervenience thesis cannot do without perfectly natural properties. We will see that the PDA proposes a better supervenience thesis that is compatible with contemporary physics.

Although some of the problems with HS are familiar, I will say a bit more about a few of them. The most discussed is that quantum mechanics posits entangled states that on their face value seem to involve relations between (among) occupants of distinct regions of space time. For example, a pair of electrons in the EPR state

EPR) $1/\sqrt{2}|UP1>|DOWN2> + 1/\sqrt{2}|DOWN1>|UP2>$

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[25] See, for example, Butterfield and Isham 1999
[26] French and Mckenzie (2012)
[27] Lewis (1999) p.226

entangles the spins of electrons in different locations by a relation that cannot be reduced to

intrinsic properties of each electron. Lewis responded by saying

> I am not ready to take lessons in ontology from quantum physics as it now is. First, I must see how it looks when it is purified of instrumental frivolity...of double thinking deviant logic...and - most of all - when it is purified of supernatural tales about the power of the observant mind to make things jump. (1986 p. xi)

There are now a number of versions of quantum theory that are purified of instrumental

frivolity and which have explicit ontologies and laws. These accounts all violate HS in one way

or another. For example, there are versions of Bohmian mechanics which include fundamental

relations of entanglement and versions in which the wave function is a kind of field occupying a

very high dimensional configuration space and others in which it is some nomological like

fundamental entity outside of space-time that directs the motions of particles.[28] Both

Everettian and spontaneous collapse versions of quantum mechanics also include the wave

function and so is difficult to square with HS. The proposal that the wave function does not

occupy space-time but directs the motions of particles that do obviously conflicts with HS.

There are conflicts with HS beyond accommodating the wave function. Proposals for quantum

gravity theories posit entities that are not point like (e.g. strings and branes), space-times that

have more than 3+1 dimensions and even ones in which space-time is not fundamental but is

claimed to emerge from something non spatial temporal that is more fundamental. So, there is

reason to think that HS is not true or at least that physicists don't feel constrained by it.

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[28]For discussions of ways of understanding the ontology of QM wave functions see Albert and Ney (2013). Michael Esfeld 2017), Eddy Chen 2020) and others have proposed versions of Bohmian mechanics whose ontology consist solely of point particles while the wave function is construed as a device for systematizing particle trajectories. This account is arguably compatible with Humean Supervenience but conflicts with certain well established features of fundamental theories. See Loewer(forthcoming).

There are problems accommodating current physics not only to HS but to the Lewisian view

that fundamental properties are categorical. Arguably quantum field theory and the standard

model violate both the strictures of HS and Lewis' proposal that fundamental

properties/quantities are categorical. French and McKenzie argue that QFT and the standard

model contain symmetry principles that individuate certain fundamental quantities and entities

and so entail that they are not categorical and that is a problem for Lewis' Humeanism.

Mckenzie and French point out that

> …the properties through which the fundamental constituents of matter interact in terms
> of gauge transformations, and these bring in their wake the appropriate gauge bosons,
> then it looks as if we have no choice but to say that the properties such as charge and
> color are not the sort of properties that lone objects can have, and hence that these
> properties are not after all intrinsic. (French and McKenzie 2012 p.45)

And Tim Maudlin adds

> We should note that adopting the metaphysics of fiber bundles invalidates a set of modal
> intuitions that have been wielded by David Lewis under the rubric of the Principle of
> Recombination. According to Lewis, Hume taught us that the existence of any item puts
> no metaphysical constraints on what can exist adjacent to it in space. This invites a cut-
> and-paste approach to generating metaphysical possibilities: any object could in principle
> be duplicated elsewhere, immediately adjacent to the duplicate of any other item (or
> another duplicate of itself) ... Duplication is supposed to be a metaphysically pure internal
> relation between items. But from the point of view of fiber bundle theory, it makes no
> sense to 'copy' the state of one region of space-time elsewhere even in the same space-
> time, much less in a disjoint space-time. There is no metaphysical copying relation such
> as the Principle of Recombination presupposes. (Maudlin 2007 p.103)

These authors claim that QFT and the standard model posit properties, fields and particles

which are not intrinsic and not categorical because they involve necessary connections

between properties, particles and fields. This renders them unsuitable to play the roles that perfectly natural properties are designed to play in Lewis' metaphysics.

Recent theories of quantum gravity and string theory make trouble for HS reliance on space-time and fundamental geometrical relations. In a recent review talk Nathan Seiberg says

> space and time will end up being emergent concepts; i.e. they will not be present in the fundamental formulation of the theory and will appear as approximate semiclassical notions in the macroscopic world. This point of view is widely held in the string community (Seiberg 2006)

A candidate best system must include a structure which accommodates its fundamental ontology. I will call this structure the system's "fundamental arena." 3+1 dimensional space time with a Euclidian metrical structure (or a relationist version corresponding to it) is the arena for classical mechanics, non Euclidian curved space-times for general relativity, and as mentioned earlier, configuration space for some versions of quantum mechanics. It may even be as Seiberg says the fundamental theory might not include a space-time as fundamental but as emerging from some more fundamental arena. This is the situation for theories like loop quantum gravity that treat space time as emergent from spin networks. For such theories Humean Supervenience is unsuitable as a metaphysical framework since HS assumes that 3+1 space-time is fundamental.

I can think of some ways in which one might save the letter of Lewis' metaphysics in the face of these examples. But an alternative would be to admit that candidates for law specifying best theories may involve fundamental quantities that are not intrinsic to points and not categorical,

and fundamental relations other than geometrical relations and alternatives to space-time as the fundamental arena while seeing if it is possible to save the core idea of the BSA. I will describe an account that does just this after discussing some further issues raised by Lewis' accounts of natural properties and laws.

Lewis' reliance on perfectly natural properties raises several further issues that are of a more strictly philosophical nature. One is that if perfectly natural properties are categorical then it appears that Lewis' account is committed to unknowable quiddities. Since a perfectly natural property is not individuated by its nomic role what does individuate it is its intrinsic nature i.e. its "quiddity." Quiddities are for properties is what haecceities are for individuals- a something we know not what- that makes it the property it is. In certain cases, categorical properties may swap roles in the laws without making any difference to the nomological structure of a world. So, for example, if negative charge and positive charge are perfectly natural then there are two possible worlds which have the same nomological structures but in which every place positive charge is instantiated in one negative charge is instantiated in the other. This leads Lewis and Langton to what they call "Ramseyan humility", the view that there are facts which are irremediably unknowable.[29] Black thinks that quidditistic distinctions are "distinctions without differences" and that "the idea of two qualities swapping nomological roles is unintelligible"[30] I am not sure that these worries carry much weight or that the view that fundamental properties are quiddities is any worse than its alternatives. But for the moment I only want to flag the issue and will say a bit about it later.

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[29] Lewis (2009)
[30] Black 2000 p94

A second more worrying issue is that since which properties/quantities are perfectly natural is a primitive fact of metaphysics there is the possibility that a true theory of the universe that physicists consider a law determining theory of everything is not the Lewisian Best System since it is not formulated in terms of expressions referring to perfectly natural properties and relations. It could thus turn out that the equations counted as laws by the TOE and those counted as laws by the Lewisian best system do not match each other. Lewis says that physics aims to locate perfectly natural properties and the fundamental properties of contemporary physics are the best candidates we have for perfectly natural properties. But physicists could be wrong about which properties are perfectly natural even if their theory optimally satisfies all the other conditions place on a Lewisian best system. Physics aims to find nature's scientific joints, but these may not coincide with her metaphysical joints. This problem, which I call "the mismatch problem", was first pointed out by van Frassen who takes it to be fatal to Lewis' account."[31]

I can think of three responses to the mismatch problem. One is to say that it is not a problem but simply a consequence of a realist account of laws. A certain kind of realist might say that there are metaphysical facts about which properties cut nature at its metaphysical joints and even a theory that satisfies all other scientific desiderata but not the metaphysical one is wrong about the laws. But it seems presumptuous for a metaphysician to say to a physicist who believes she has found a theory that optimally satisfies all the scientific criteria but not the metaphysical one that she may not have discovered the laws since the theory is not

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[31] The mismatch problem is discussed by van Frassen (1989) and Demarest (2015) who suggested its name.

formulated in the language of perfectly natural properties. If one thinks, as I do, that it is physics not metaphysics that determines where nature's joints are this response is not appealing.

A second response is that the mismatch simply cannot arise due to the role of perfectly natural properties in determining reference. According to Lewis perfectly natural properties are "reference magnets." He proposes an account of predicate reference on which the most basic terms of the ideal best system must refer to perfectly natural properties and the reference of non-basic predicates is determined by the complexity of their definitions in terms of basic predicates.[32] Here is a suggestion for how the idea might be implemented to respond to the mismatch problem.[33] In actual theory building fundamental predicates are introduced as theoretical terms by a theory positing connections between them and observation and other already interpreted terms.   For example, "is an electromagnetic field" is introduced by connecting it with circumstances that produce an electromagnetic field like running a current in a wire and its manifestations like its deflecting a magnet. The proposal is that the reference of the new predicate is the most natural property that satisfies the conditions that introduce it. That natural property acts as a magnet so the predicate refers to it excluding less than natural properties from being the predicate's reference. If the theory is true and fundamental, then the property is perfectly natural. This would be lovely if it could be spelled out convincingly. I see two problems. One is that it is not clear that or how it applies to the scientifically ideal language whose full set of basic truths are systematized by the best system. It's predicates may have

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[32] Lewis suggested this response to me in conversation.
[33] Ted Sider suggested this in conversation.

complex definitions in the language whose basic predicates refer to perfectly natural

properties. Second, it simply assumes that the reference of the predicate is a perfectly natural

property. But why should that be the case? What is it about a Lewisian perfectly natural

property that makes it as opposed to other properties that satisfy the conditions the

predicate's reference? Lacking an argument to the effect that the properties that satisfy the

recombination principle are also reference magnets this question is unanswered.[34] The third

response to the mismatch problem is the PDA as I will explain shortly.

There is another problem concerning natural properties in the BSA that is closely related to

the mismatch problem. Shamik Dasgupta calls it "the problem of missing value."[35] The problem

is that if naturalness is a metaphysical primitive there needs to be an explanation of why

physics should consider laws characterized in terms of perfectly natural properties valuable. It is

not sufficient to respond that laws are involved in explanation since that just raises the

question of why explanation characterized in terms of laws involving perfectly natural

properties is valuable. Natural properties are posited by Lewis as part of a theory of possible

worlds and modality and in accounts of reference and intrinsic. Why should these properties

also be the ones involved in determining the regularities that physics consider lawful?

Dasgupta observes that instead of formulating the best system in terms of systematizing all the

facts specified in the language of perfectly natural properties one could formulate it in terms of

a language whose primitive predicates refer to the perfectly natural* or perfectly natural**

properties and so on and such systems plausibly will determine different laws. The question is

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[34] Even if Lewis' very intriguing suggestion can be made to work it doesn't touch the other problems that motivate the PDA.

[35] Dasgupta (2018)

"what is it about perfectly natural properties that guides physical theorizing and determines which propositions are laws?" It is not adequate to answer that "they are the ones that guide physical theorizing because they are perfectly natural" or because "they cut nature at the joints." Why should the properties that play the role of determining metaphysical possibility/necessity via the recombination principle be exactly those that play the role of determining the laws on the BSA? The issue is that a metaphysical primitive is supposed to have a normative force on physics in that it determines what counts as "the best" scientific theory of the world. The problem is that without an explanation of why it has such normative force we have no more reason to think that the best theory formulated in the language of perfectly natural properties rather than the best theory formulated in the language of perfectly natural* properties determines the laws. Dasgupta concludes that an account of their value is missing from Lewis' perfectly natural properties.[36] He argues that accounting for the value that laws and our division of the world into what we call fundamental properties is to understand these as *relative* to us and our values and worries that this may lead us into a pernicious anti-realism. I will argue that the PDA finds the missing value without sliding into pernicious relativism.

The mismatch and missing value problems result from the fact that on Lewis's version of the BSA candidates for the best theory systematize the distribution of instantiations of Lewis's perfectly natural properties and these are metaphysical primitives designed to deal with a host

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[36] Dasgupta observes that it is ironic that Lewis raises exactly the missing value problem to accounts of objective probabilities which take them to be metaphysically fundamental propensities. Objective probabilities are supposed to be credence guiding via Lewis' Principal Principle and its ilk, but Lewis thinks that there is no explanation of why a metaphysically primitive propensity should guide credence. P.5 I just paraphrased Lewis' famous objection to anti-Humean conceptions of objective chance, because my objection to realism is exactly analogous. Ironic, then, that the problem with realism can be found in the writings of someone I take to be an arch realist! But ironies aside, let us review Lewis' argument so as to use it as a guide

of metaphysical issues. Whether there is a single kind of property that can play all the roles

that Lewis requires of perfectly natural properties is questionable and has been questioned.[37]

The worry I am raising is not just this but that Lewis' perfectly natural properties are

characterized without reference to the aims of physics. The PDA remedies this by proposing an

alternative account of what candidates for the best system systematize and how to evaluate

these candidates that attends to the aims of fundamental physics. In the course of doing this it

addresses a number of other problems with Lewis' BSA.

IV. The PDA

Lewis describes his version of the BSA as a "package deal" since it is a package that includes

perfectly natural properties, laws, and objective chances. But it is a package in which the

perfectly natural properties and a space-time are metaphysically fundamental while the laws

and chances are derivative on the distribution of properties throughout the space-time. So, the

deal is one in which the perfectly natural properties and a space-time have priority.

Metaphorically speaking "they wear the pants." In contrast, the PDA is a package in which

neither properties, the arena in which they are instantiated, nor laws have priority over the

other, but all are determined together. To explain how I need to briefly discuss the goals of

fundamental physics.[38]

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[37] By Loewer (2007, Eddon and Meacham (2014), Dorr and Hawthorne (2013)

[38] The idea of developing a Humean account of laws as a package deal in which the best system determines both laws and the properties that figure in them was proposed in Loewer (2007) and somewhat differently in Cohen and Callender (2009). The former invoke this approach to fundamental laws and properties while the latter apply it as well to special science laws and properties.

Physics begins with the investigation and explanation of quotidian macroscopic phenomena and especially with the motions of material objects e.g. planets, projectiles, pendula, pointers and so on in the 3+1-dimensional space of our ordinary experience and extends from there with the aim of covering all physical phenomena. One of the great ideas in the history of physics is that macroscopic objects are composed of an enormous number of microscopic constituents- material particles or atoms- whose motions determine the motions and other behavior of the macroscopic objects they compose.[39] Our understanding of the concept of an atom involves the claim that they are the constituents of ordinary macroscopic physical objects. Laws describing the behaviors of atoms are posited to explain how that can be. For example, laws governing the motions of atoms account for macroscopic thermodynamic phenomena. Specifying laws that cover the motions of atoms involves introducing further properties and entities; mass, charge, subatomic particles, the electromagnetic field, the quantum mechanical wave function and so on and laws that cover them. It may also involve introducing a space-time whose geometry differs from the geometry of ordinary experience or even a fundamental arena from which space-time emerges. In the course of these developments the notion of what an atom is may change but it is always with an eye to accounting for the behavior of the macroscopic objects that we began with. The aim is to find a theory whose fundamental arena, ontology, properties and laws is sufficient to account for macroscopic objects and their behaviors as well as

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[39] Richard Feynman put the point this way when asked for one sentence describing the most important scientific knowledge to be passed on if all other scientific knowledge were destroyed as "I believe it is the atomic hypothesis that *all things are made of atoms — little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another.* In that one sentence, you will see, there is an enormous amount of information about the world, if just a little imagination and thinking are applied."

whatever non-fundamental items and their behaviors that are introduced along the way. Such

a theory would be a Weinbergian TOE and according to the PDA a law specifying best system.

Whether or not the actual world is amenable to such a TOE is an open question but the history

of physics makes it plausible that it is and, in any case, shows that searching for one has been

highly fruitful in locating candidates for fundamental ontology and laws.[40]

The Package Deal Account (PDA) assumes that the universe has or is close to having a

system that is like a TOE in that it systematizes truths concerning its fundamental ontology. If it

turns out that our universe has no TOE then the PDA says that the system that comes closest to being a

TOE as long as it is sufficiently close is the law giving system.

The PDA is similar to Lewis' BSA in that it identifies laws in terms of their participation in

systematization. But unlike the BSA it rejects the view that the fundamental ontology consists

of the instantiation of metaphysically primitive perfectly natural properties throughout a

geometrically structured space-time in favor of the view that fundamental ontology and laws

are specified together as a "package deal." Since the PDA doesn't demand an ontology whose

fundamental entities/magnitudes are categorical it is not committed to Lewis' recombination

principle and is not strictly Humean. But preserves the Humean view that propositions express

laws in virtue of their place in a systematization and it is compatible with a Humean ontology.

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[40] Although Newtonian mechanics is not true illustrates what a TOE might look like. In Newtonian mechanics physical objects (planets etc.), gases. liquids and light are composed of elementary particles and their motions are systematized by dynamical laws that specify the evolution of an isolated system's state. When supplemented with laws specifying the statistical mechanical probability distribution and the low entropy macro state of the very early universe this package is arguably (Albert 2000 and Loewer 2018) able to account for most macro phenomena (at least if one does not look too closely).

The PDA works like this: Assume that the world can be described in a by many different languages all of which are capable of describing macroscopic phenomena in familiar ways but may differ in the predicates/relations that can qualify as referring to fundamental properties and relations and describing the fundamental arena. For example, these may include "x is an electron", "x has charge of e electron volts", "x is 3 meters from y", "x has spin 1". Languages may differ only in the predicates each designate as fundamental. The PDA associates with each world W a triple consisting of a fundamental language L, a fundamental arena A, and a fundamental theory T, <L,A,T> as follows: For each language L take the complete description of W in terms of the instantiations of the fundamental predicates of L throughout A, and consider the theory T(L) that best systematizes the fundamental truths of W as expressed in terms of L. Consider all the triples <L,A,T>. The Best systematization T for W is the scientifically best of these. A is W's fundamental arena, the *scientifically* determined fundamental properties/relations of W are the properties referred to by the fundamental predicates L and the laws of W are propositions entailed by T.

It may turn out that for the actual world there isn't a unique optimal language-arena-theory triple but many that are counted as equally good by the criteria for evaluating fundamental scientific theories. This seems almost inevitable since it is plausible that what is basic for one language will be defined for another and the reverse. In this case there aren't unique scientifically determined fundamental properties but alternatives. The possibility of there not being a unique set of consequences of a world's best systematization and so the set of laws or the fundamental arena is not unique may seem more problematic. There is not much worry if the alternative systematizations agree on the laws (though not on which are fundamental). But it seems possible

that for the actual world there may be systems that are optimal but differ, at least a little, on which propositions they count as laws and on the arena.[41] Lewis envisioned this possibility for his version of the BSA and suggested that the laws are propositions entailed by all optimal systems. I think a better proposal is to accept that being a law is system relative.

The extent of disagreement systems that optimally satisfy the criteria for evaluating candidate systems depends on exactly what these criteria are. As mentioned earlier Lewis suggest simplicity and informativeness presumably because these are desirable in a systematization and appealed to in physics. But his characterizations of simplicity and informativeness are inadequate and there are more criteria that physicists appeal to when evaluating proposed fundamental theories. By improving on Lewis' characterizations and adding further criteria it is plausible that the worry about competing law determining optimal systems will be somewhat alleviated.

Since the PDA dispenses with a single collection of metaphysically prior perfectly natural properties whose instantiations are what candidate systems aim to systematize another way is needed to fix the truths that candidate theories aim to systematize so as to avoid trivialization of VxFx. While VxFx may be maximally informative given Lewis' notion of informativeness in terms of possibilities excluded it does not express information the way scientific theories must if they are to be useful to scientists to provide predictions and explanations of macroscopic phenomena. As Jaag and Loew say in a recent paper a law determining best systematization should be "best for us."[42] A theory is useful for us (more generally physicists) if information can be extracted from

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[41] Although two systems may disagree on which generalizations are laws since laws must be true the generalizations must be mutually consistent.
[42] Jaag and Loew (2018)

it that is expressed in languages we use for describing macroscopic phenomena. To accomplish this a fundamental theory needs to be supplanted with principles that underlie connections between fundamental and macroscopic and other non-fundamental sentences. Assuming that the fundamental language and system is Newtonian an example of such a principle might be "If there are particles at such and such positions with such and such momenta then there is a solid rock in region R." Principles connecting the more fundamental with the less fundamental play a role in explanation. For example, we can explain why a there is a quartz rock at a particular location in terms of there being a certain arrangement of SiO4 molecules. The explanation appeals to a principle connecting arrangements of molecules with quartz rocks. Some philosophers think of these principles as *a priori* and analytic and others as *a posteriori* substantive grounding principles.[43] I won't discuss their nature further here except to note that they do not add anything to the fundamental ontology/properties and laws of a package deal and they are simple and systematic.[44]

    The criteria for evaluating candidate systems are determined with an eye toward their resulting in systems that provide scientifically significant information in forms that are useable to scientists for prediction and explanation. These criteria have been developed and refined during the history of physics since the first proposals for law specifying theories. Especially

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[43] For example, Dave Chalmers (2012) thinks the connections as *a priori* discoverable by conceptual analysis while Jonathan Schaffer (2017) construes them as substantive grounding principles. The issue of the metaphysical and epistemological status of the principles that connect the fundamental to the non-fundamental is important and difficult. My own view is that understanding theoretical terms e.g. "atom" involves understanding the role it plays in a theory that explains antecedently understood phenomena. On this view connecting principles are epistemologically but not metaphysically substantive.

[44] By "systematic" I mean that they systematically connect arrangements of fundamental with less fundamental in terms of the properties of each. For example, arrangements and motions of gas molecules are connecting with gasses at various temperatures and pressures. The requirement that connecting principles are simple and systematic excludes the proposal that the fundamental system is simple and informative while the connecting principles are complicated and unsystematic.

important is the extent to which a candidate system supports predictions and explanations of fundamental events and regularities, events and regularities of the special sciences and more generally of phenomena that come to be seen as important to the scientific community.

While I can't provide anything like a complete list of the criteria operative in fundamental physics for evaluating candidate systems or an account of how to balance them there have been a number of suggestive proposals in recent discussions. With a debt to recent papers by Dorst, Hall, Hicks, Callender, Loew and Jaag here is a tentative list.[45]

i)   T is simple and unified. It has no redundancies or idle parameters.

ii)   Every event T takes to be fundamental falls under its laws

iii)   T's dynamical laws are deterministic or at least Markovian.; i.e. the dynamical laws and the state of the universe at a time screen off its state at previous times

iv)   Many sub-systems can be treated as almost isolated so that in typical circumstances the laws apply to them neglecting their environments

v)   Its laws are mathematically tractable or have mathematically tractable approximations

vi)   T enables predictions, explanations and understanding of a wide variety of phenomena via systematic perspicuous principles that connect fundamental to non-fundamental descriptions.

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[45] Ned Hall (2020) and Craig Callender (2009) also make the point that Lewis' criteria of "simplicity and informativeness" need to be clarified and added to. Hall mentions that to apply laws we typically need a distinction between dynamical laws and initial conditions, Callender mentions some of the other criteria on my list, Jaag and Loew (2018) focus on the importance of a system being usable by us, and Dorst (2019) on its role in predictions

vii)   T allow for a distinction between initial conditions and dynamical laws so as enable

the characterization of counterfactual and hypothetical inferences.

viii)   Fine tuning of constants is minimized

I don't mean that all of criteria (1)-(xiii) must be completely satisfied by the optimal law giving system but rather that the optimal system achieves the best balance among the degrees to which they are satisfied. All are in need of clarification and elaboration and it is likely that there are further criteria that can be gleaned from an examination of practice in physics and the special sciences. As sciences develop these criteria may evolve and new ones develop. But that is work for another paper. Here I will make just emphasize that (xi) plays an especially important role in the PDA. A fundamental theory should, as Wilfrid Sellars expressed it, enable us to descry the *manifest image of the world* in terms of the *scientific image of the world.*

My proposal then is that in evaluating candidate language-arena-theory triples one looks the criteria that are implicit in the practice of physicists in their evaluation of candidate systems. The Best system of the world is the true theory-language that would if all the facts expressed in its fundamental language known be the one (or ones) that best balance these criteria.

According to the PDA the fundamental laws are axioms of the world's best system and a proposition is nomologically necessary iff it is a consequence of the world's best theory. Not every nomologically necessary proposition is considered to be a law but only those that play a significant role in unifying a domain that is scientifically interesting. Lewis' restricts lawful propositions to those that express regularities. But on my account it a specification of the

fundamental state of the world is among the axioms of the best system it also may count as a law. Plausibly this is the case for the specification of the low entropy state of the universe at the time of the big bang at David Albert calls "The Past Hypothesis."[46] It has been argued that the past hypothesis plays a crucial role in accounting for the second law of thermodynamics and also in accounts of counterfactuals and special science laws.[47]

According to the PDA a world's fundamental properties and relations and its fundamental arena is determined by its optimal language-arena-theory triple. We can think of these as playing the role in the PDA that Lewis' perfectly natural properties and space-time play in his BSA. But they are not quite different. The are determined by science not by metaphysics. There is no requirement that fundamental properties and relations conform to the requirements of Humean Supervenience. In particular, an optimal <L,$> may posit properties that are not instantiated at points, relations other than geometrical relations e.g. quantum mechanical entanglement relations and a fundamental arena that is not 3+1 space-time.

Another way in which the PDA differs from Lewis' BSA and HS is that its fundamental properties need not be categorical. Since the fundamental properties and laws are determined together the fundamental predicates of <L,A,T> can be interpreted as referring either to categorical or to properties that are wholly or partially individuated by laws. It follows that necessary connections are compatible with the PDA. If T contains the law that whenever F is instantiated at location L1 then G is instantiated at location L2 R related to L1 the properties referred to by F and G can be interpreted so that they necessarily satisfy this law. So, if "is a

[46] Albert, D. (2000)
[47] Loewer, B. (2007b)

fermion" and "is a Higgs field" are basic predicates of the optimal theory of our world then there is an interpretation on which it is impossible for there to be fermions without there being a Higgs field. Whether a fundamental predicate is interpreted as referring to a categorical property or to a nomologically individuated property and if the latter which laws are individuated is a matter of which interpretations are better for the purposes of scientific explanation. The important point is that either interpretation is permissible on the PDA. From this vantage point the dispute between those who like Lewis think that fundamental properties are categorical and those who think that they are nomologically individuated appears to lapse.[48]   Necessary connections introduced in this way don't compromise the PDA's Humean credentials since it is still the case that laws systematize regularities and don't enforcing them. Since a theory earns its status together with fundamental properties by systematizing their instantiations throughout the arena supervenience still holds. Thus the PDA counts as a Humean account of laws.

The PDA handles a number of issues that arose for Lewis' BSA. It is not committed to HS or to any prior metaphysical conditions on space-time (or the arena that plays the role of space-time) or on fundamental ontology. It is able to accommodate quantum mechanics, gauge theories, string theory, spin networks and so on. Also, it is not committed to metaphysically prior natural properties that are categorical so, as just discussed, allows for necessary connections among fundamental properties. This should alleviate Lewis worry about quiddities. Fundamental

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[48] A consequence is that the PDA's fundamental properties may not satisfy recombination and so can't be used to characterize possible worlds. Also, it is plausible that it is possible that there are alien properties that are not references of fundamental terms of (L) and so possibilities not captured by recombination applied to these properties even if they are all categorical.

properties/quantities are what they are in virtue of their roles as elements of an optimal language-arena-theory triple. They have no need of an unknowable quiddity to provide their identities.[49]

Since the laws and properties are determined together as a package by the true system that best satisfies the conditions that science places on fundamental theories the mismatch problem cannot arise on the PDA. The PDA also points towards a solution to Dasgupta's missing value problem without sliding into pernicious relativism. Commitment to the criteria that are used to evaluated candidate best theories are the source of the value that scientists find in describing the world in terms of the language of a best theory. It is also the source of the value of laws since they ground the role of laws in explanation, prediction, supporting counterfactuals. A candidate best system has value in virtue of its role in making the world understandable to us. Although "to us" introduces an element of relativism this much relativism does no damage to scientific realism. The best theory must be true and to extent to which a theory/language satisfies the criteria is factual. Whether our world has a best theory that comes sufficiently close to satisfying the criteria and if so what it or they are is an objective matter.

The PDA claims that the laws supervene on the distribution of property/relation instantiations throughout the arena of the optimal package of laws, properties, and arena. In this way it preserves the Humean view that laws are not primitive modal constrainers or

[49] Michael Esfeld's (2017) "Super Humeanism " also avoids quiddities. It accomplishes this by proposing an ontology that consists only of permanent point particles related by distances. This account's ontology is compatible with the PDA since it could turn out that its ontology is the optimal arena and ontology for the actual world but it also may turn out that the optimal ontology has no primitive point particles but concerns fields occupying a manifold that lacks primitive distance relations. Further, it fails to satisfy some of the criteria required of the optimal system, in particular (iii).

producers of events. However, it would be possible for a non-Humean to react to the PDA by saying that while the PDA may provide evidence, even very strong evidence, that the propositions that it deems laws are laws it is not their being elements of the systematization that makes them laws but rather that the are laws only if they constrain or produce the distribution of events.[50] It is constraining or producing that makes them laws. The Non-Humean might go onto claim that the best systematization of the actual distribution by the lights of the aims of physics misleads regarding the laws and fundamental ontology. These claims strike me as attempts to hold onto intuitions formed by the theological birth of the concept of laws in the 17th century.[51] Holding onto them without God involves positing primitive entities that somehow force nature to obey regularities. themselves on nature.[52] As Hall (2020) observes giving up these intuitions doubtlessly involves a certain amount of revisionism concerning related concepts e.g. objective chance, causation, and explanation. This is a project that has occupied philosophers with Humean inclinations in recent years.

The PDA presupposes that reality can be described in many different languages none of which is metaphysically privileged but one or more may be scientifically privileged. Fundamental laws systematize the distribution of truths in the fundamental language and the totality of fundamental truths together with connecting or grounding principles account for non-fundamental truths. The unusual feature of the PDA is that it is not committed to a specific ontology of, say particles or fields and particular fundamental properties/relations but instead to reality whose ontology and so on is shaped by ideal physics. This raises the question of what

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[50] This is suggested by Ned Hall in his (2020) pp. 15-17.
[51] See Peter Harrison (2019) for a discussion o the theological origin of the idea of laws of nature in the 17th century.
[52] The view that laws are primitive entities that enforce regularities is forcefully argued for by Maudlin (2007).

reality can be like at its most fundamental metaphysical level if doesn't come already prepackaged in terms of fundamental properties etc. What is the best way of thinking about the fundamental metaphysics that underlies this view? I can't get into this question with the thoroughness it deserves but I do want to suggest that the metaphysical framework that Jonathan Schaffer calls Monistic Structural Realism" (MSR) may be friendly to the PDA.[53] As I understand it MSR holds that the fundamental object is the whole cosmos. This is the monism part. Since on the PDA whether a predicate or law is fundamental depends on the systematization of the entire universe it is monistic. Further the property of the universe's possessing a certain best system or systems is a structural property intrinsic to the whole cosmos. This is the structural part. The Supervenience base for the laws is the complete truth in the optimal fundamental language and the connecting principles map it onto non-fundamental truths concerning macroscopic objects etc. This is the realist part.

The PDA is a descendent and I believe improvement over Lewis' BSA. Like Lewis' Humean BSA it rejects governing laws and law determining powers. But unlike Lewis' BSA its account follows more closely the aims of physics and the criteria physicists appeal to in order to achieve them than on *a priori* metaphysics. By rejecting Lewis' reliance on metaphysically given perfectly natural properties while maintaining the basic idea of his BSA the PDA results in an account of laws and fundamental properties that is friendlier to contemporary physics and an account that to an extent transcends the debate between Humeans and certain non-Humeans. Because it provides an account of the scientific joints of the world that doesn't rely on *a priori*

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[53] Schaffer (2010) and (2019)

metaphysics it rejects the ultra-realists view that, in Putnam's words, there is a "ready-made

world"[54] and replaces it with a more pragmatist but still realist metaphysics of fundamental

laws.

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