I am very grateful for this invitation. During the 10 years I was on the faculty at USC I came to the colloq every year ..the first year I was here Dan gave "Where am I" …and learned a lot…One of the things I learned was that the Sunday morning talk was designated as the "technical talk". It was usually a talk about philosophy of mathematics, modal logic, space-time and so on.. with lots of symbols numbered sentences perhaps a proof or two and so on….and I learned that there was a good reason for scheduling the technical talk on Sunday morning. For the first two days of the colloq there were invariably- as in the present colloq- excellent stimulating talks of wide philosophical interest and few symbols. The saturaday talk is always- as D's talk last night- enormously funny. And it is followed by partying in some cases until thw wee hours. The consequence is that most of the paritcpants inclding the speaker arrive on Sunday morning- if they arrive at all- having had their fill of philosophy, sleepy, and with hangovers. These are all excellent reasons to place the technical talk on Sunday morning since very few people will follow it anyway… but I will disappoint you ..at least in this regard…. There are few technicalities..

Draft: Version with footnotes, references, glaring errors corrected will be available prior to the Colloq.

Laws and Natural Properties

My topic is the connection between laws and natural properties. I am particularly interested in David Lewis' Best System Account of laws and chances (the BSA aka the MRL account) and its connections with his metaphysically realist and Humean view of perfectly natural properties. Lewis' account of natural properties/relations involves a metaphysically fundamental distinction that identifies a special class of properties he calls "the perfectly natural properties." His account of natural properties is "Humean" in that it specifies that perfectly natural properties instantiated in one region of space-time have no necessary connections to natural property instantiations in

wholly distinct regions. Lewis' BSA account of laws is also Humean in that it claims that laws are the regularities entailed by the ideal scientific theory of the world. I am very much attracted to the BSA primarily because it connects laws and chances with the criteria of law hood and objective chances employed in physics and because it eschews mysterious entities like fundamental propensities and mysterious metaphysical relations of *governance and guidance* that allegedly hold between more metaphysically construed laws and events. However, I will argue that the way Lewis employs natural properties in the BSA account of laws is problematic. It undermines the connection between the BSA and scientific practice and it overburdens the notion of natural property with work it cannot perform. I will then sketch a version of the BSA that doesn't depend on Lewis' account of natural properties. The significant difference between my account and Lewis' is that where he invokes *naturalness* as a metaphysical primitive and explains laws partly in terms of it, my account involves a genuine "package deal" that characterizes laws and scientifically fundamental properties together. I call it the "Package Deal Account"; the PDA.

Let's begin with a review of Lewis' main ontological theses. Lewis is most well known for his view that reality includes not just the actual world and its contents but an infinitude- a large infinitude- of possible worlds and that all these worlds are concrete totalities.[1] Each world is constituted by some kind of space-time structure and by concrete entities of various kinds with various properties distributed throughout the spatial-temporal structure. Lewis doesn't say much about possible space-time structures but I suppose that they are manifolds with topological and geometrical structure. (e.g. for example Newton's absolute space and time, Galilean space-time, Minkowski space time, various GR curved space-times.) Perhaps some manifolds are many, even infinitely many, dimensional and perhaps some involve nothing that counts as a time dimension perhaps not even spatial dimensions. The main idea is that they provide the stage on which the events of the world evolve.[2] Lewis doesn't say much about the possible fundamental concrete

[1] Lewis says that the actual world is one of the possible worlds no different in kind from any of the others. It is actual – for us- because we inhabit it.

[2] When Lewis talks about space-time structures he sounds like a substantivalist about space-time but perhaps he is willing to countenance worlds at which relationism obtains. Items belong to the same world iff there is a space-time relation between them.

entities that can occupy a space-time (not necessarily the actual space-time). I suppose that putative examples are Newtonian point particles, quantum mechanical particles, strings, fields of various kinds, gunk, wave functions, homogenous spinning spheres, souls. The concrete entities that exist at a world are the merelogical sums of whatever fundamental concrete entities exist at that world. Lewis says that entities belong to the same world in virtue of being located in the same manifold/space-time (or being spatio-temporally related) and no entity belongs to more than one world. This latter, of course, means that talk of identity through possible worlds must be construed in terms of counterpart theory.

Lewis thinks that his account of possible worlds as concrete realities and the various doctrines that go along with it (the account of actuality and counterpart theory) are to be preferred as the best explanation or systematization of our modal talk and a great deal else connected to it. Like most others I don't buy it. I prefer a more deflationary account of metaphysical possibility and a view of "worlds" as certain collections of propositions. However, that is not my topic this morning. I believe that neither Lewis' account of laws nor the account of laws that I will propose nor Lewisian or other plausible accounts of nomological notions-chance, counterfactuals, causation- depend on his particular account of possible worlds. So although I will continue the discussion within Lewis' framework I maintain that everything important that I will say about laws can be carried over to other accounts of possibility and possible worlds.

Properties/relations are the semantic values of predicates and Lewis identifies them with classes of possible entities/classes of ordered n-tuples of possible entities. So, for example, the semantic value of "is a tiger" is the property of being a tiger and that is a class that includes all the tigers that inhabit (did, do, and will inhabit) the actual world and all other possible worlds.[3] Non synonymous predicates may refer to the same property and most properties are not referred to by any predicate of our language. Lewis calls this account of properties "the abundant conception of properties." In "New Work for a Theory of Universals" he says that he came to think that reality also includes a distinction of enormous metaphysical signficance between perfectly natural

[3] If "is a tiger" is vague then it is associated with a class of classes that are eligible values.

properties and the rest. He suggests that this distinction is metaphysically primitive or that it may be explained in terms of primitive notions of *universal* or *similarity*[4]. Lewis' reason for positing perfect naturalness (or universals) - like his argument for concrete possible worlds-is the role that it can play in explanations and systematizations of many other notions. Among these are analyses of exact duplicate, certain supervenience theses, the intrinsic/extrinsic distincion, qualitative property, law, counterfactual, causation, projectible property, and reference.[5] Perfect naturalness also plays a central role in his account of possibility via a recombination principle that says, roughly that possible worlds can be cut up into regions and these regions can be duplicated and recombined to form other possible worlds. For example, there are possible worlds containing unicorns since there are worlds containing regions occupied by white horses, worlds containing wings, and worlds containing horns, and these various regions can be duplicated and knitted together to form a world containing a unicorn.[6]

Although *naturalness* is primitive Lewis says a lot about natural properties that specify them and the work that he intends for them. The main ones are:

1 Each world is associated with a class of fundamental natural properties/relations that are instantiated (or can be instantiated) at that world.[7]

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[4] 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 now of any account that works. In any case, only perfectly natural properties figure in my discussion.

[5] 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.

[6] Lewis' idea is that there are natural property instantiations intrinsic to the regions occupied by the horse, the wings, and the horn and that these regions can be knitted together to yield an animal with wings etc that are not merely attached to the horse but, as it were, grew out of the body.

[7] Natural properties not associated with w are said to be "alien to w." Exactly which natural properties are associated with w? Lewis' view seems to be those instantiated at w plus others that are related to these in certain ways. For example, the property of having a mass of exactly 10kg may not be instantiated at w but is still natural at w since other mass properties are instantiated at w. Perhaps any determinate of a property one of whose determinates is natural and is instantiated at w is *associated* with w.

2. *Naturalness* is a matter of metaphysical necessity; a property that is natural with respect to one world is natural with respect to all worlds although associated with only some.

3. Natural properties associated with a world are fundamental and form a supervenience base for all other properties instantiated at that world and more generally for all the propositions that are true at that world. In other words, if W and U are worlds that are associated with the same class of natural properties and agree on their space-time structures and on the distribution of natural properties then they agree on all propositions.

4. Entities that satisfy the same natural properties/relation (and whose parts are similarly arranged and satisfy the same natural properties) are qualitatively perfectly similar (duplicates) to each other.

5. Natural properties are intrinsic to the individual or region of space at which they are instantiated.[8]

6. There are no necessary connections between natural properties instantiated in wholly distinct regions.

7. Natural properties are categorical. This means that natural properties are individuated independently of laws and causal relations.[9]

8. Although natural properties are not individuated by laws they are law-involving (in a way that I will describe shortly)

9. In our world (and world's like ours) it is the job of the sciences- especially fundamental physics- to find the laws and natural properties associated with the actual world.

All this is a very heavy metaphysical load for one distinction to carry. I am skeptical that there is any single kind of property that can do all the work that Lewis assigns to natural properties and I am also skeptical that all this work can or needs to be done at all.[10] But here I will focus only

[8] I am not sure what fundamental entities Lewis thinks instantiates fundamental natural properties. He speaks of them being instantiated at space time points and regions but perhaps he thinks that some worlds contain fundamental individuals of various kinds (e.g. particles, strings, fields, etc.) that instantiate them.

[9] More generally, there are no necessary connections between properties instantiated in disjoint regions. It follows from a property being intrinsic to a region that it is individuated independently of laws that connect it to properties instantiated in distinct regions.

[10] Maya Eddon and Chris Meacham argue that Lewis' notion of natural property cannot do all the work that Lewis asks of it in their paper "No Work for a Theory of Universals"

on the role of natural properties in Lewis' account of laws. The gist of my argument is that Lewis' metaphysical notion of natural property is not needed- in fact creates problems- for his account of laws. Before getting to a discussion laws I want to briefly describe Lewis' views about the kinds of natural properties that are instantiated at the actual world.

Lewis thinks that the fundamental natural properties associated with the actual world implement two contingent metaphysical theses: Physicalism and Humean Supervenience. Physicalism is the supervenience claim that any world that *minimally* duplicates the space-time distribution of the physical natural properties/entities and laws at the actual world duplicates it *simpliciter*. Lewis (like most of us Physicalists) doesn't say what makes a property physical but he does say that it is the job of physics to identify the natural properties of the actual world and his examples of good candidates- *mass, charge, spin* - are properties (or magnitudes) that are posited in by fundamental physical theories. If all perfectly natural properties are physical then since perfectly natural properties form a supervenience base at the actual world for all truths it follows that any world that is a minimal *physical* duplicate of the actual world is a duplicate *simpliciter*.[11]

Humean Supervenience makes two claims about the natural properties associated with the actual world. One is that the perfectly natural properties are instantiated by points of space-time or by point size entities. The other is that the only natural relation is distance between space-time points. So any world that *minimally* duplicates the Humean properties and relations of the actual world duplicates it *simpliciter*.[12]

HS and Physicalism are independent contingent propositions. There are worlds at which both, none, one but not the other, hold. Physicalism is supported by the empirical successes of certain

[11] W and U are duplicates *simpliciter* iff their space-times are isomorphic and they differ at most in the individuals that occupy their respective space-times.

[12] "Humean supervenience is named in honor of the great denier of necessary connections. It is the doctrine that all there is to the world is a vast mosaic of local matters of particular fact, just one little thing and then another...We have geometry: a system of external relations of spatio-temporal distances between points...And at those points we have local qualities: perfectly natural intrinsic properties which need nothing bigger than a point at which to be instantiated. For short, we have an arrangement of qualities. And that is all. There is no difference without difference in the arrangement of qualities. All else supervenes on that." (1986 p. ix)

fundamental physical theories – particularly classical mechanics and quantum theory- and arguments for the plausibility of the possibility of reducing non-physically characterized features of the world to the ontologies of those fundamental theories. Part of HS- the part that says that there are no necessary connections between natural properties that are instantiated in wholly distinct regions- follows from Lewis' general views about possible worlds and natural properties. HS goes beyond this and says that the natural properties associated with the actual world are instantiated by points (or point size entities) and that the only natural relation instantiated in the actual world is spatial temporal distance. Lewis thinks that these claims are supported by or at least compatible with the ontology of (at least some) of the proposals for successful fundamental physical theories although, as we will see, not others. He says that what he wants to fight against are philosophical accounts of various notions particularly laws, chances, causation, identity through time, that are incompatible with HS. He has in mind, for example, accounts of causation in terms of fundamental necessary connections between events and accounts of fundamental entities that construe them as extended in space-time. His main defense of HS is to construct HS compatible accounts of laws, chance, causation, motion, and other scientific notions.

By 1986 Lewis was aware that there are tensions between HS and the ontologies of certain theories that physicists have been and are taking as serious candidates for fundamental theories. The conflict is especially clear in the case of quantum mechanics. The heart of the conflict involves what Schrödinger called "quantum entanglement." It is this feature of QM that is responsible for QM violations of Bell's inequality and so for QM nonlocality. The quantum state or wave function of a pair (or any number) or elementary particles located in distinct regions may fail to supervene on (be determined by) any physical state that quantum mechanics assigns to the individual particles. The simplest example is the singlet state of a pair of particles one in region R and the other in region L.

$$1/\sqrt{2}|x\text{–up}\rangle_R|x\text{–down}\rangle_L - 1/\sqrt{2}|x\text{–down}\rangle_R|x\text{–up}\rangle_L$$

On the orthodox interpretation the outcomes of measurements of the same component of spin for the two particles are anti-correlated but there is no determinate spin for either electron. A measurement of any component of spin will result in a value for that component. In other words, the state of the pair of the electrons is not determined by the states of the electrons separately.[13] In 1986 Lewis said

[13] The electrons don't have quantum states at all individually but they are in what are called "reduced" states determined by the singlet state. In this case the reduced states determine the probabilities of the outcomes of

> 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 doublethinking deviant logic; and- most of all- when it is purified of supernatural tales about the power of the observant mind to make things jump. If, after all that, it still teaches nonlocality, I shall submit willingly to the best of authority. (1986 xi)

Given the state of the philosophical interpretation of QM (both in physics and philosophy) in 1986 this attitude may not have been an unreasonable. But the situation is now quite different. There are a number of realist observer independent interpretations of quantum mechanics purged of any notions that consciousness collapses the quantum state that are currently taken seriously in the philosophy of physics literature. I have in mind Bohmian mechanics, GRW collapse theories, and many worlds accounts. All these involve construing the quantum state as (or as representing) an element (but in some cases not the only element) of reality. These accounts (and specific versions of them) involve different ways of understanding the quantum state. I won't go into details here except to say that all are incompatible with HS. My own view is that the wave function is best construed as a field in infinite dimensional configuration space which is the fundamental space. The fact that space appears 3 dimensional at the macroscopic level is a consequence of worlds' Hamiltonian; i.e. the way forces operate to evolve the wave function.[14] While this particular account preserves the part of HS that says that fundamental magnitudes (in this case the wave function density) are instantiated at points, the points are those of infinite dimensional configuration + time-space not three+one space-time. Other interpretations construe the quantum state as involving fundamental entanglement relations or properties instantiated by whole systems or as a kind of non-Humean law. On each of these accounts the quantum state associated with a particle is not intrinsic to that particle or the region it occupies (i.e. the three dimensional region it occupies). I should add for those not familiar with these matters that quantum entanglement is not a rare phenomenon but is essential to molecular and generally material structure. There are proposals in quantum field theory to the effect that every part of a field is entangled with every other part.

There are other conflicts between HS and physics.[15] String theoretic entities, vector and tensor fields, gauge magnitudes, and even classical particles are all difficult to square with HS. For example, worlds in which identical particles recoil when they meet and worlds in which they pass through are distinct but HS makes no distinction. Rather than go into this in detail let's just declare

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measurements of the components of spin but don't determine whether these outcomes will be anti-correlated. Quantum non-locality follows from the existence of entangled states.

[14] See David Albert (2000)

[15] See *The Metaphysics within Physics* by Maudlin (2006) and Arntzenius (2006)

that HS is dead - as far as the actual world is concerned. Quantum mechanics shows not only that HS is false but also makes it difficult to see how natural properties can perform all the tasks Lewis assigns to them. For example, since the chemical bonds that hold a unicorn's horn to its head involve quantum mechanical entanglements it is not at all clear that the recombination principle can provide us with unicorns. You just can't take a QM system that constitutes a horn and another thar constitutes a horse and place them next to each other to get a unicorn. But this doesn't matter for Lewis' account of laws and chances since they presuppose that fundamental properties are perfectly natural but not HS.

Lewis accounts for laws and chances together by building on a suggestion of Ramsey's.

> 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)

Chances enter the picture by letting deductive systems include sentences that specify the chances 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. (1995 p.480)

As Lewis says axiom systems are more or less strong (informative), more or less fit the facts, and are more or less simple. Fit is a kind of informativeness. A probabilistic theory informs about the facts by specifying probabilities that in turn guide our beliefs. These features of deductive systems trade off. Strength and fit can often be improved at the cost of simplicity and visa versa. By assigning probabilities to types of events systems sacrifice strength for fit but may also make great gains in simplicity. The best system is the one that gets the best balance of the three while not both implying that q and that the chance that q is less than 1. The laws are the generalizations entailed by the best system for that world. Among the laws may be regularities that mention chances; e.g. for any tritium atom the chance of its decaying in time interval t is x.

Each of the notions "simple", "informativeness", "fit", and "best" require more elucidation than Lewis gives them or that I can get into here. Briefly though, Lewis thinks of simplicity as an objective property of expressions in a language e.g. a second order differential equation is simpler

than a 4th order equation (other things being equal), a conjunction is less simple than either of its conjuncts, etc. He identifies the informativeness of a sentence with the number of possibilities it excludes. This is a rather crude measure since any sentence excludes infinitely many worlds and so only sentences related by entailment can be compared. I will make a different suggestion for evaluating information later. Lewis may have left out some features that physicists think of as important for evaluating proposed total theories of the world. For example, it seems that comprehensiveness is not quite the same thing as informativeness but is a significant requirement. For now I want to say that the right way- though I am not sure it is how Lewis thought of it- the conditions characterizing a best theory for a world as conditions that are implicit in the practice of fundamental physics. It is plausible that physicists look for systems that are true, simple, informative, and comprehensive and perhaps satisfy further conditions. The nature of these features and their relative weighting is grounded in the tradition and practice of physics. No doubt the practice leaves some leeway concerning evaluating simplicity, informativeness and so on. But it is not implausible that even so our world is so rich and complicated that all the admissible ways of precisifying them will count the same generalizations as laws.

I will call the propositions that the BSA identifies as laws L-laws and the chances specified by L-laws L-chances. Of course Lewis thinks that the L-laws and L-chances are the laws and chances. I will briefly discuss some competing accounts in due course.

How is Lewis' BSA account related to his account of natural properties? Lewis observes that if there are no constraints on the language in which potential best systems can be formulated then the account collapses into triviality. Consider the predicate "Fx" that is true of all and only the individuals that exist at the actual world (recall that individuals exist at just one world). Lewis says that the system (x)Fx is true, simple and maximally informative. It is maximally informative since it entails all truths; i.e. in any world at which (x)Fx holds all and only the actual truths hold. So every true generalization is counted as a law. Lewis' response is to restrict the languages in which candidate systems are formulated to those whose simple predicates/function terms refer to natural properties and says that "Fx" fails to qualify.

How is the BSA related to HS? The claim that the BSA specifies laws is a piece of analysis. If true it is supposed to be a necessary truth.[16] HS is contingent. The requirement on

[16] Lewis thinks that there is no world that contains non-Humean laws. But perhaps there are worlds that contain non-Humean entities that play the role of laws better than L-laws do even though the actual world is not one of them. If so then we might want to say that the BSA account of laws also contingent. Assuming

languages eligible to formulate systems competing for the title Best System" doesn't require that the only relation terms are geometric or that the space is three dimensional. So the death of HS doesn't undermine the BSA of laws. Of course the condition that natural properties are categorical is presupposed by the BSA. If natural properties weren't categorical then laws connecting natural properties would be prior to L-laws and the BSA would not be an account of the laws. It could turn out that the L-laws and the "laws" that individuate properties are not at all the same.

Although the BSA account doesn't presuppose HS it is a Humean account of laws since it identifies laws with certain regularities and which regularities are laws supervenes on the distribution of properties that themselves are not individuated in terms of laws or necessary connections. Let's look more closely at the BSA.

The BSA is an account of *fundamental* laws. Newtonian mechanics with a complete compendium of force laws (and with a probability distribution over initial conditions to account for statistical mechanics) is an example of a Best System- but not of our world. Quantum field theory and General relativity are theories that claim to be parts of or approximations to parts of a Best System; perhaps a successor to these theories that reconciles them is the BS of our world. Assuming physicalism such a theory would provide a complete specification of the nomological structure of the world.

Lewis' Humean account is a vast improvement over previous regularity accounts (for example , Reichenbach's and Goodman's and those that were Armstrong's target in 1980). So that we may appreciate this here is a list of its virtues:

1. If it is an L-law that p then p.
2. There is a distinction between L-lawful and accidental regularities
3. There may be vacuous L-laws
4. "it is an L-law that" creates intensional contexts. So it may be an L-law that Fs are followed by Gs and F and F* are co-extensional while it is not an L-law that F*s are followed by Gs.
5. The account is not restricted to the simple and unrealistic philosophical illustrations of laws e.g. Fs are followed by Gs but can count Hamilton's equations, Maxwell's equations, Schrödinger's equation and so on as laws.

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the natural property distinction, there are worlds at which the BSA specifies the laws but at which HS is false and there are worlds whose natural properties satisfy HS but where there are non-Humean laws.

6. L-laws are laws of fundamental physics since they are formulated in the language of fundamental natural properties. But the worlds Best System may entail special science laws in virtue of the relations between fundamental physical and special science properties.
7. There is an internal connection between L-laws and the criteria (e.g. simplicity) physicists employ in formulating fundamental theories.
8. Since laws supervene on the distribution of properties they are not ontologically mysterious and no mysterious notion of *governing* is involved.
9. Similarly L-chances also supervene on the distribution of natural property instantiations thus avoiding mysterious propensities or degrees of propensities.
10. The account extends smoothly to provide Humean accounts of objective probabilities and that account extends nicely (*pace* Lewis) to objective probabilities when the dynamics is deterministic.[17]
11. The account of objective probabilities provides a *rationale* for connections between objective probabilities (and beliefs about objective probabilities) and subjective degrees of belief e.g. Lewis' PP.

Unfortunately I don't have time to discuss the best system account of objective probabilities and the features 8 to 10 except to say that seeing how it can be extended cover probabilities was what persuaded me that it is on the right track.[18]

Despite all of its attractive features there are philosophers who say that L-laws (and L-chances) are not genuine laws (chances). They think that Humean regularities, no matter how special, are too weak to perform the jobs that laws perform. It will be easier to discuss these objections after briefly describing the main non-Humean competitors to Lewis' account.

We have to take a step back to fundamental properties since the two main types of non-Humean accounts are built on two different accounts of fundamental properties.[19] An account associated with David Armstrong (Dretske and Tooley) agrees with Lewis that fundamental law involving properties are categorical. That is, no law is essential to a fundamental property. Laws are features

[17] Lewis thought that the only objective probabilities are connected to dynamical laws but a strong case can be made for the objectivity of probabilities occurring in statistical mechanics and Bohmian mechanics which are both deterministic theories. By adding a probability distribution over initial conditions of the universe a system of dynamical laws (as in classical mechanics) can be made much stronger with just a little added complication. See Loewer 2001, 2006.

[18] I discuss accounts of objective probabilities based on the BSA in "David Lewis' Account of Objective Chances", "Chance and Determinism", and "Counterfactuals and the Second Law"

[19] Carroll (19xx) discusses and criticizes various accounts of laws. Also Carroll (20xx) is an anthology that contains papers supporting various accounts.

of reality that are metaphysically *distinct* from (and don't supervene on) fundamental property instantiations. On Armstrong's particular account it's a law that Fs are followed by Gs iff there is a relation he calls "a relation of contingent necessitation" between the universals *F* and *G*. The existence of this relation somehow makes it the case or brings it about that Fs are Gs. This characterization of laws sits uncomfortably with the kinds of fundamental laws posited in fundamental physics which are typically expressed by differential equations that specify the rates of change of various magnitudes and vectors. A more sophisticated account along similar lines suggested by Tim Maudlin simply says that laws are themselves fundamental elements of ontology characterized by equations that *govern* the evolution of state. I will call these M-laws. Metaphorically, when God created the universe he created the initial conditions of space-time and distribution of fundamental entities and magnitudes *and also* the M-laws. The M-laws then evolved the initial state to produce the history of the universe. M-Laws are thus essentially dynamical and essentially connected to a preferred direction or orientation of time.[20]

The other type of anti-Humean account of laws (associated with Shoemaker, Swoyer, Bigelow, etc.) involves an anti-Humean account of fundamental properties on which they are essentially dispositional. Laws are assimilated to certain metaphysically necessary connections resulting from these dispositions. For example, Newtonian *mass* is the property it is in virtue of, or partly in virtue of, its instances being connected to other property instances so as to conform to the gravitational law, F=ma, and so on. I will call the laws based on this proposal N-laws. N-laws are necessary truths but the are *a posteriori* since it is *a posteriori* which properties are instantiated at a world.

The issue of whether fundamental properties are categorical or dispositional or some mixture is, in a certain sense, prior to the nature of laws. I find it to be one of the most puzzling problems in metaphysics. As far as I can see each view is problematic.[21] On the positive side the view that fundamental properties are categorical lends itself to recombination principles and so to Tractarian accounts of possibility. However, categorical natures have seemed to some philosophers to be mysterious and unknowable (Lewis and Shoemaker). A bizarre consequence is that, for example, the properties *mass* and *charge*, assuming these are fundamental, can swap roles in

[20] Maudlin's account is developed in *The Metaphysics Within Physics.* The idea is that the dynamical laws take the state at t and *produce* the next state. The metaphor of production connects this account with temporal direction. Of course there need be no "next" state. This makes talk of the laws and the state producing or governing the evolution of state even more puzzling. Alternative accounts of the relation between time and laws are Monton (20xx) and Loewer "Time and Law".

[21] Troy Cross' Ph.D. dissertation at Rutgers 2001 contains a superb discussion of the various views of fundamental properties.

fundamental laws. The dispositionalist account doesn't allow for this possibility but has the consequence that laws are metaphysically necessary and that ever so slight a change in the laws involves a change in the properties involved in the laws. Some philosophers (Russell, Foster, Blackburn) suggest that if all there is to a property consists of dispositions of its instances to produce (and be produced) by instances of properties whose nature consists entirely in the web of dispositions then the world dissolves into potentiality without actuality. The view that fundamental properties have both dispostional and categorical natures essentially may seem to avoid these problems but it raises the question of how these two natures are connected to one another. The whole issue has the feeling of a Kantian-like antinomy for which there is no solution short of rejecting assumptions of the problem. In any case, I have no solution but I will suggest an account of laws that if it doesn't solve the issue at least holds promise of bypassing it.

It will now be easier to understand the problems that advocates of M and N laws have with Lewis' BSA. They see L-laws as "laws-lite" incapable of doing the work that laws are do in the sciences. The main objections to the BSA are that L-laws[22]

a) fail to explain
b) fail to support counterfactuals,
c) cannot be rationally supported by evidence
d) leads to inductive skepticism
e) dependent on our interests but genuine laws are objective
f) are contrary to intuitions we have about laws and chances.

These objections have been much discussed in the literature on laws. The first four objections I think have been satisfactorily answered (by Lewis and to an extent in my "Humean Supervenience"). They involve either mistakes or begging the question against Lewis' account. But perhaps a word or two about the (e) and (f) would be useful here. On Lewis' account which generalizations count as laws is dependent on the notions of simplicity, informativeness, and these are determined by the practice of fundamental physics. So, in a sense, L-laws are determined by the interests of physicists. On the M and N accounts laws are as constituitively independent of scientific methodology as stars are, and it must be admitted, that this is the way physicists usually think of laws. There are a number of remarks that can be made that take some of the wind out of this objection. First, it is not a consequence of the BSA that the truth of any lawful generalization e.g. Schrödinger's equation is dependent on or determined by anyone's interests. As far as truth of the content of a law is concerned the account is compatible with the most uncompromising realism. What is relative to criteria of simplicity and so on is that a generalization is a law. But of course, it is not relative to any particular person's interests but rather to the interests and methods

[22] Armstrong (19xx) and Carroll (19xx) are good sources for objections to Humean accounts.

of the tradition of the community of physicists. Further, it is plausible that the L-laws are fairly stable over reasonable variation in the criteria of simplicity, informativeness etc. An advocate of the M or N account of laws who view laws as involving a fundamental aspect of reality (M-laws or N-connections) that are in no way constituted by scientific practice will find this reply inadequate. But they then have a problem of explaining how on their account scientific method and the criteria scientists use for laws has anything to do with their metaphysical accounts.

Objection f involves the fact that we can conceive have worlds that are exactly alike with respect to their distribution of categorical natural properties but apparently differ in their laws and chances. There are a number of such examples due to Carroll, Toole and others. Earman describes two worlds; w and u. Each contains a single particle moving uniformly but the laws of w are all the laws of classical mechanics and the law of u has is the single law "all particles move uniformly." The BSA has the consequence that the L-law of both worlds are "all particles move uniformly" but so if w is possible laws are not L-laws. I think that the right response for a proponent of the BSA is to admit that the proposal is slightly revisionary. The explanation of w's apparent possibility is that our concept of a law is an amalgam containing both elements of a governing view, a necessary connection view and a Best System's view. Insofar as our intuitions are influenced by the governing view w seems to be possible. But whether w is genuinely possible depends on whether laws are best understood as L-laws or M or N laws and this is a big question that cannot be decided by intuitions alone.[23]

A thorough defense of the BSA requires showing that L-laws can do all the legitimate work that laws do in the sciences, an explanation of intuitions that are contrary to it, and arguments against alternative accounts. There are two main problems with the anti-Humean accounts we have discussed. One is that I find the idea of M and N laws *governing* or *producing* the evolution of events incomprehensible. How does an M-law take the state at one moment and *produce* subsequent states? Production suggests a causal notion but that cannot be what is meant here since causation is a non-fundamental relation between events. The other problem is that since neither M nor N-laws have internal connections with the criteria physicists employ in deciding on laws it is not clear why these criteria should have anything to do with discovering M and N laws even if our world contains them. Why should a theory meeting the criteria of physics (simplicity, informativeness, comprehensiveness etc.) tell us anything or be likely to tell us anything about the M or N laws? If one can show that L-laws do the work that laws do in science and that more

[23] An instructive comparison is with our concept of free will. It plausibly contains both libertarian and compatabilist elements. Compatabilists argue that although our intuitions provide support for incompatibalism that notion is problematic and a compatabilist concept of freely acting can be constructed that does all or most of the work that needs to be done by our concept of free will.

metaphysically committed accounts are problematic than that would I think justify the degree of revisionism in our concepts..

The issue between Humean and non-Humean accounts of laws is far from settled. But instead of pursuing it further here I want to discuss an objection to the BSA that involves the way in which natural properties enter into the account. The objection is related to a line of thought Bas van Frassen raises in Laws *and Symmetries* but I will take it in a different direction.

The problems is this: Given Lewis' account it is an epistemic possibility that physicists propose a fundamental theory T that meets all the requirements that the tradition and practice of fundamental physics puts on a fundamental theory of the world and yet still T does not specify the correct L-laws. The reason is that T is not formulated in a language whose simple predicates correspond to perfectly natural properties. Suspending for the moment skepticism about whether there are perfectly natural properties it is epistemologically possible that T better meets these requirements than any theory formulated in the language of natural properties. In fact it is not clear that T's satisfying the requirements for a best theory provides *any* reason at all for thinking that any of its generalizations are L-laws. The problem is that naturalness is a *metaphysical* feature of properties that Lewis posits in order to perform various metaphysical jobs. Why should the criteria that physicists employ in evaluating proposals for fundamental theories for Best Theories involve properties that can perform these jobs?

Recall that Lewis motivated the introduction of natural properties into his characterization of laws because the system axiomatized by (x)Fx (where "Fx") is a predicate true of all and only individuals that exist at the actual world) apparently maximizes simplicity and informativeness and so counts as the best system of the world. The consequence is that all true generalizations are laws. Lewis' remedy was to add the requirement that the atomic predicates in the language of a Best Theory refer to perfectly natural properties- where these are properties that do all the metaphysical work Lewis assigns them. But this isn't why a physicist would reject (x)Fx as a fundamental theory. The reason, obviously enough, is that it fails to provide information about the world in a way that gives us explanations, predictions, understanding of how the macro supervenes on the micro and so on in ways that are salient. And the reason for that is even though we know that (x)Fx is true from they way it has been specified we don't know what proposition it expresses in a way that we can extract information from it; information about the motions of planets, the brightness of stars, the results of chemical reactions, and so on. Instead of rejecting (x)Fx (or other patently useless theories) by hitching the account to a particular metaphysical account of properties, a better response is to place further *scientific* requirements on a Best Theory. This

response is in the spirit of Lewis' original idea that the notion of law is characterized in terms of scientific practice but unlike Lewis' account it would be a genuine "package deal" account of laws and law involving properties together. If we follow this path there is no prior metaphysical constraint on the language or properties of candidate theories but also no guarantee that the properties determined in this way are perfectly natural in Lewis' sense.

Instead of positing that candidates for Best System are all formulated in the language of perfectly natural properties I propose that we evaluate languages L and systems T formulated in those languages together. Call this "the package deal account" (PDA). Unlike Lewis, who seems to take the fundamental space-time geometry as given (and so not part of T) the PDA includes the space-time theory as part of the package by allowing L to include geometrical notions and T to specify geometrical relations. The PDA is not constrained by HS or by the requirement that its fundamental vocabulary denotes properties intrinsic to space-time regions. L may also contain fundamental relational predicates other than geometrical ones, gauge theoretic notions, terms referring to vector magnitudes and so on. There are no restrictions on the theories language or ontology that come from outside of science. Of course if this is to work there will have to be more conditions on a best theory than Lewis' simplicity, informativeness, and fit in order to pick out a unique Best Theory. I am not sure exactly what those conditions are but the place to look is at the candidates for complete or parts of complete fundamental theories of the world that have been seriously considered within physics. While these theories differ in their ontologies and laws and we know that none of them or any straightforward combination is the Best theory of our world there are features they share that suggest conditions that are relevant to evaluating prospective candidates for Best System. One of these features, the one that immediately explains why Lewis' (x)Fx fails as a fundamental theory, is that an adequate fundamental theory must, at least in principle, provide information in a way that connects descriptions of the world in L with descriptions of macroscopic systems in terms of macroscopic variables e.g. positions, motions, pressure, temperature and so on. Ideally it would be possible to "read off" from a description of the physical situation in L of a region R of space at time t the situation in the region concerning macro variables and it would be possible to use the laws of T to deduce the description in L of the situation in R at subsequent (and prior) times and deduce the macro description at these times.[24]

[24] David Chalmers and Frank Jackson claim that a complete description of the world in the fundamental vocabulary and fundamental laws (and a statement that these are a complete description of the world and all the fundamental laws) not only entails (metaphysically necessitates) all contingent truths but *a priori* implies all truths. (Chalmers 1996, 2002 and Jackson 1998, Chalmers and Jackson 2xxx) If we accepted their claim then we could require this of the candidate L/T pairs. In that case one could in principle *a priori* "read off" macro truths from fundamental truths. I am quite sympathetic to their claims as regard to macro descriptions that are not mental (there are complications involving mental concepts) but don't want to commit myself here so I leave "read off" here unexplained.

I will call the properties, relations, magnitudes, vectors etc. denoted by the fundamental vocabulary of the Best L/T for world w "fundamental law" (FL) properties, relations…." etc of w. Others call such properties "fundamental natural kinds" but for various reasons that is not a term I like. FL properties etc. are not Lewis' perfectly natural properties The distinction between fundamental law properties etc. and other properties is a *scientific* distinction made by the goals of ideal physics and contingent nature of the world and is not a metaphysical given. A consequence is that whether or not a property is a fundamental law property at w is a contingent dependent on w while perfectly natural properties are necessarily so. Perfectly natural properties are stipulated by Lewis to be Humean; i.e. no necessary connections between their instantiations in wholly distinct regions. However, there is nothing in the PDA that precludes there being necessary connections among fundamental law properties. For example, the Pauli exclusion principle may turn out to be a theorem of the Best theory of our world and it might be construed as a necessary truth concerning electrons. (No two electrons can occupy the same quantum state *simultaneously*.) The Best L/T may simply not specify whether property referred to by a predicate is categorical or dispositional. If so then the reference of a fundamental predicate of L might be understood either as a property that is individuated in terms of the laws of T or a property that T contingently. For me this metaphysical neutrality is an attractive feature of the PDA since the metaphysical issue of whether fundamental properties are categorical or dispositional or mixed seems, as mentioned earlier, something of a Kantian antinomy. By rejecting the assumption that there is a unique *metaphysical* structure to the world we may be able to avoid the antinomy.

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