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Two accounts of laws and time

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Abstract Among the most important questions in the metaphysics of science are "What are the natures of fundamental laws and chances?" and "What grounds the direction of time?" My aim in this paper is to examine some connections between these questions, discuss two approaches to answering them and argue in favor of one. Along the way I will raise and comment on a number of issues concerning the relationship between physics and metaphysics and consequences for the subject matter and methodology of metaphysics.

Keywords Laws · Chance · Time's arrows · Humeanism · David Lewis · David Albert · Tim Maudlin

Among the most important questions in the metaphysics of science are "What are the natures of fundamental laws and chances?" and "What grounds the direction of time?" My aim in this paper is to examine some connections between these questions, discuss two approaches to answering them and argue in favor of one. Along the way I will raise and comment on a number of issues concerning the relationship between physics and metaphysics and consequences for the subject matter and methodology of metaphysics.

1 Preliminary metaphysical map

The main division in the metaphysics of laws and chances is between accounts that are broadly Humean and those that are broadly non-Humean. Humean views are

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so-called because like Hume, or rather the standard view of Hume, they eschew fundamental nomological modalities.[1] Contemporary Humeans about laws hold that the totality of the universe consists of the distribution of fundamental categorical properties/quantities and relations instantiated by fundamental entities (particles, fields etc.) throughout all of space–time. This distribution is called the "Humean mosaic". A property is categorical if its instantiation in a region of space time don't metaphysically necessitate anything about property instantiations in wholly distinct regions. Humeans claim that there is no fundamental necessity in nature connecting spatio-temporally non-overlapping events in non-overlapping portions of space–time. True nomological claims, counterfactuals, causal and probabilistic claims are certain propositions are made so by the Humean mosaic. So according to Humean views worlds that agree on their Humean mosaics also agree on their laws, objective probabilities, causal relations and counterfactuals. This is not quite what David Lewis calls "Humean Supervenience" since that doctrine additionally requires that the fundamental properties are instantiated by points or point size entities and that the only fundamental relations are geometrical and topological relations of 4-dimensional space–time. I don't make these additional conditions in the following.[2]

In contrast, non-Humeans think that there is fundamental necessity in nature. Some non-Humeans hold that nomological necessity resides in fundamental properties/quantities themselves. They thus deny that all fundamental properties are categorical. At least some fundamental properties are claimed to be such that it follows from their natures that if one is instantiated in a region some other properties are instantiated in distinct regions. On this view nomological necessity is a species of metaphysical necessity.[3] For example, gravitational mass instantiated in region R has the nature of producing an attractive force field in distinct regions. Laws, on this view, are certain generalizations whose truth follows from the natures of fundamental properties. Other non-Humeans hold that laws are themselves fundamental features of reality. On this view laws are (or are associated with) fundamental entities that are over and above the Humean mosaic that "governs" and constrains the mosaic.[4]

On both Humean and non-Humean accounts a fundamental lawful proposition and a proposition characterizing the state of a system entail subsequent states or the probabilities of subsequent states of that system. So each account says that according to it laws and events *scientifically* determine (or determine the

[1] "Humeanism" regarding laws and chances has no commitment to Hume's theory of impressions and ideas, his epistemology, or his account of meaning. Where it agrees with the historical Hume as he has been usually understood is in its denial of fundamental necessary connections in nature and in its reductionism regarding laws and causation.

[2] Lewis thinks of Humean Supervenience as a contingent doctrine that may be true of our world. In 1984 he worried that quantum theory is incompatible with HS due to quantum entanglement and he was right to worry. See Lewis (1986), Maudlin (2007) and Loewer (1996a, b, 2007b). However there are modifications that save the basic Humean idea of no necessary connections between distinct existences and the BSA account of laws and chances (Loewer 1996a, b).

[3] Shoemaker (1980, 1998) and Bird (2007) hold this view.

[4] For example, Armstrong (1983) holds that laws are relations of "contingent necessitation" between properties and Maudlin (2007) holds that laws are entities that produce the evolution of state.

probabilities of) and explain events. The distinction between metaphysical and scientific determination will feature importantly when I contrast a Humean and a non-Humean account of laws in Sect. 5.

The main issue concerning the metaphysics of time involves the origin and nature of the distinction between past and future or, what is usually called, "time's arrows."[5] Nothing is more obvious than this distinction and the fact that many familiar processes proceed from past to future but not in reverse. Chief among temporal asymmetries is the pervasive increase of entropy described by the second law of thermodynamics. Increase in entropy is exemplified in the melting of ice, the diffusion of gas, the burning of wood, the passing of youth, and pretty much all macroscopic processes. Other arrows of time include the facts that we can exert some control over the future but never over the past, there are records including our memories of the past but not the future, we see the past as closed and the future as open, fear future but not past dentist visits and so on.

How are the arrows of time related to one another and what grounds them? Non-reductionists about time hold that there is a *metaphysically fundamental* arrow of time that grounds the distinction between past and future and is essential to the explanation time's arrows. In contrast, reductionists make no appeal to a metaphysical arrow of time but instead attempt to explain the distinction between past and future and all the related arrows in terms of fundamental laws and patterns of distribution the occupants of space–time. The most promising reductionist approach involves attempting to explain time's arrows in terms of or related to the increase in entropy described by the second law. In Sect. 4 I discuss one way of accomplishing this.

While these two metaphysical issues—Humanism vs. non-Humanism about laws/probabilities and reductionism vs. non-reductionism concerning the direction of time—may, at first, seem unrelated they are intimately connected in the two metaphysical accounts of laws and time that I will discuss. These two are Tim Maudlin's non-Humean and non-reductionist account of laws and time as spelled out in his superb book *The Metaphysics within Physics* and a Humean and reductionist account that derives from David Lewis' influential account of laws and David Albert's work on time's arrows in his superb book *Time and Chance*. In comparing these two accounts I don't mean to suggest that they are the only accounts of laws, chances, and time worth taking seriously. But I do think they are the two of the most interesting accounts and the two that are most easily applicable to the fundamental laws of physics. In the end of the day (or by the end of this paper) a proponent of another view might view the objections I will discuss against each of these views as supporting her own favorite alternative.

[5] The other main metaphysical issues regarding time are between tense and non-tense theories of time (between A-theorists and B theorists) and the issues between so called presentists, growing block theorists, and eternalists. Positions on each of these issues are closely connected to positions on others and in particular with views about the direction of time. Tense theorists take the distinction between past and future as grounded in tensed facts the growing block theory has a built in direction. As will be clear Maudlin's view makes no appeal to tensed facts or growing blocks.

2 Maudlin on laws and time

According to Maudlin the fundamental laws of physics are themselves metaphysically fundamental elements of ontology. That is, they are entities, in a very broad sense, although they don't fall into any of the usual ontological categories; properties, relations, individuals, space, abstract mathematical structures, etc. Maudlin thinks we should recognize laws as belonging to a *new* category of ontology. They are entities that *produce* or *govern* and thereby *explain* the evolution of events. He doesn't say much about fundamental probabilistic laws but the analogous view is that they "produce" the chances of future evolutions of a state. And although he doesn't explicitly discuss the metaphysics of chances the view that best fits his account of laws is that chances are also primitive elements of reality; something along the lines of propensities or degrees of propensities. The chance of E given S is the degree of the propensity of S (perhaps in certain circumstances C) to produce E. In order to avoid prejudging the issue of the best way to understand physical probabilities I will call Maudlin's laws and chances M-laws and M-probabilities. On this account a proposition is lawful if it is made true by the operation of M- laws and true propositions about objective chances are made true by propensities.[6]

Maudlin also holds that "time passes."[7] He endorses Newton's famous remark that time "of itself, and from its own nature, flows equably without relation to anything external".[8] But what does Maudlin mean by time "flowing" or "passing"? He makes it clear that he doesn't mean that there is something that is literally flowing relative to something else like a river flows past its banks.[9,10] Rather, his view is that time, unlike, space, possesses an intrinsic direction; an arrow. Each point of space–time is associated with an arrow that points in a direction that is toward "the future" of that point. In Newtonian space–time all the arrows are aligned in the same direction. In relativistic space–times the light cones associated with a point are fundamentally distinguished between "future" and "past" cones.[11]

[6] An M-law has no location in space–time although it governs events in space time and Maudlin has suggested that it is possible that different laws operate in different regions of space–time.

[7] Maudlin says "I find that I am strongly inclined to a view that strikes many of my colleagues as lunacy. I believe that it is a fundamental, irreducible fact about the spatio-temporal structure of the world that time passes." The view doesn't strike me as lunatic or unprecedented or even unpopular among philosophers. But, I will argue it is obscure and unexplanatory.

[8] Scholium to Definition 8 of the *Principia* in Newton (1999).

[9] Although Maudlin isn't averse to speaking of the rate at which time passes—he says it is "one second per second" he doesn't literally propose that time is flowing relative to some super time and talk of its rate plays no role in his account.

[10] Some philosophers who speak of time flowing/passing hold that so called "tensed-facts" are fundamental and irreducible to tenseless facts. This is not merely a claim about the irreducibility of tensed *propositions* to tenseless *propositions* but the stronger claim that the a fact expressed by a true tensed statement relative to its context fails to supervene on the totality of tenseless facts. The picture that often goes along with this view is that of a moving Now that travels up a tree of possibilities fixing the past as it goes. This is not what Maudlin has in mind when he speaks of time passing. As far as I can tell his view is compatible with a 4-dimensionalist conception of space–time and with the reducibility of tensed statements.

[11] In a relativistic space–time points that lie outside of the light cones of a point are neither in that point's future nor in its past.

In Maudlin's view it is this intrinsic directedness that distinguishes, for example, two particles moving towards each other from their moving apart, growing old from "growing" young and so on.

According to Maudlin what makes the intrinsic direction of time special (in a way that an intrinsic direction space, if there were one, would not be) and underlies the distinction between past and future is the close connection between it and the operation of M-laws. Maudlin says

> … The passage of time connotes more than just an intrinsic asymmetry: not just any asymmetry would produce passing … the passage of time underwrites claims about one state "coming out of" or "being produced from" another, while a generic spatial (or temporal) asymmetry would not underwrite such locutions

Maudlin's proposal then is that the passage of time consists in the fundamental arrows of time determining the direction in which laws operate. Call these "M-arrows" (and the temporal direction the M-direction).

M-laws and M-arrows are made for each other. The direction of the M-arrow "tells" an M-law the direction in which to "produce" the "next" state and temporal direction is the direction from past to future because it is the direction that the laws evolve the state. On Maudlin's view a possible world that lacks M-laws and M-arrows also lacks laws, and time. It also lacks causation, processes, and change. Such a world would consist at most of a jumble of disconnected directionless momentary events. Maudlin, thinks, of course, that the actual world is not like that.

3 Lewis account of laws and chances

Lewis proposed a Humean version of "the best systems account (BSA) of laws and chances." According to the BSA laws are certain true propositions and equations that are entailed by the ideally best scientific systematization of the totality of fundamental truths of the world. Since the Humean mosaic determines the best theory the account is Humean.[12] Lewis proposes that candidates for best theory are formulated in a fundamental language whose simple predicates correspond to the natural properties that comprise the Humean mosaic. The best scientific systematization is the true theory formulated in this language that best combines simplicity and informativeness and, perhaps, other theoretical virtues.[13] Lewis thinks of

[12] Lewis' version of the BSA assumes that the language in which candidates for Best System are formulation in a language whose simple predicates/terms denote perfectly natural properties and quantities. He also assumes that in the actual world all fundamental properties are instantiated at points or by point size entities (or fields that have values at points) and that the only fundamental relations are geometrical. As mentioned earlier (footnote 3) HS as Lewis characterizes it is unacceptable in view of quantum entanglement (Maudlin 2007). In Loewer (2007b) I explore the possibility of formulating the BSA without presupposing metaphysically given perfectly natural properties and without assuming that the fundamental properties are categorical.

[13] Lewis says "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

simplicity as an objective property of a system's simplest axiomatization 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.[14] These characterizations are vague and rough and require improvement but the idea behind them seems to be this. There are features of candidates for a fundamental theory of the world that the scientific tradition, especially the tradition of fundamental physics, prizes in a theory. Lewis mentions the features simplicity and informativeness but it may be that there other relevant features e.g. comprehensiveness, unity, symmetry, that should go into the characterization of the Best Theory.

Whether or not our world has a systematization good enough to be counted as a Best Theory or whether there are ties for the honor or whether for every good systematization there is a better one depends on the Humean mosaic. The successes of physics to date provide reason to think that our world is susceptible to very good systematizations in more or less fundamental terms. We can think a Best Theory is what fundamental physics is aiming for; what Steven Weinberg dreams of when he dreams of a "Final Theory."[15] From this point on I will assume that our world does have a unique best theory whether anyone ever formulates it or not. In order not to prejudge the issue of the nature of laws I will call the propositions that the BSA identifies as laws "L-laws." Of course Lewis thinks that the L-laws are the laws. Should it turn out that our world has no Best Theory (or the best theories do not have enough in common) then there are no L-laws. It will be back to the drawing boards for Humeans.[16]

The BSA includes objective probabilistic laws by including expressions for conditional probability functions in the language in which candidate best theories are formulated. The probability expression are interpreted by their role in determining the best theory where best theory is now understood as the theory that best combines simplicity and informativeness including informativeness about the Humean mosaic by way of probabilities. Lewis understands probabilistic

Footnote 13 continued
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) Lewis imposes the requirement that the candidates for best systematization are formulated in the language of perfectly natural properties in response to a worry that without some such restriction the best system account collapses. In (Loewer 2007b) I argue that the BSA can be formulated without assuming a metaphysically prior category of properties.

[14] This is a rather crude measure since any sentence excludes infinitely many worlds and so only sentences related by entailment can be compared.

[15] Weinberg (1992). It is important to keep in mind that candidates for Best Theory systematize all the fundamental truths not the empirical truths. And if our world does have a best theory, and even if scientists manage to formulate it, it is plausible that they won't know it is the true theory since it is plausible that there are other empirically equivalent (but false) theories that seem to equally well satisfy all the scientific virtues.

[16] Though there are "fall back" Humean positions should the world fail to have a best theory. If there are ties laws could be identified as generalizations that belong to all best theories or laws could be indexed by best theories.

informativeness in terms of fit; i.e. the likelihood of the Humean mosaic given the candidate theory. The idea is that by specifying probabilities a candidate system may gain a great deal of informativeness while still being relatively simple.[17] For example, consider a long sequence of the outcomes of measurements of x-spin of a y-spin electron. Typically, a simple description of the sequence in a language lacking probability functions will not be very informative and an informative description will be very complicated. But the proposition that the probability of a measurement of x-spin on a y-spin electron yields an "up" result is .5 and that the measurements are independent may be both simple and informative. I will call the objective probabilities that are specified by entailments of the Best theory L-probabilities.

The BSA account of laws and probabilities makes no appeal to primitive laws, necessary connections, fundamental causal relations, fundamental counterfactuals, dispositional properties or, as Lewis would say, to any "non-Humean whatnots.". The truth maker of law claims is the Humean mosaic.[18] On the one hand, this can be seen as a virtue since it renders L-laws and L-probabilities metaphysically non mysterious; or at least no more mysterious than the Humean mosaic and the notions *simplicity, informativeness*, and *best theory*. On the other hand, some see Humeanism as a defect that renders L-laws incapable of doing the explanatory work that laws are supposed to perform. The heart of the objection is that since the lawfulness of a proposition G depends on the distribution of fundamental facts G cannot turn around and explain any of those facts. I address this worry in Sect. 5.

4 The Albertian account of the arrows of time

The most promising approach to reductive accounts time's arrows involves connecting them to the temporal asymmetry found in the second law of thermodynamics. The second law, as it was first formulated, says that the entropy of an energetically isolated macroscopic system never decreases and typically increases over time until the system reaches thermodynamic equilibrium. Entropy and equilibrium are thermodynamic properties of macro systems that are characterized in terms of their relationships with other thermodynamic quantities; energy, pressure,

[17] Lewis says "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" (1994, p. 480). Lewis proposes evaluating the informativeness of a probabilistic theory in terms of the "fit" of the world on the theory i.e. the likelihood of the world on the theory. This is problematic since it is plausible that the likelihood of the actual world on any plausible candidate theory is infinitesimal. See Elga (2004) and Loewer (2001) for some discussion of this point.

[18] Lewis' also assumes that the actual world conforms to a thesis he calls "Humean Supervenience." HS says that the natural properties of our world are instantiated at points of space–time or by point size entities and that the only natural relations are geometrical. The existence of so-called "quantum entangled states" seems incompatible with HS (Loewer 1996b; Maudlin 2007). Fortunately, BSA can be developed without assuming HS (Loewer 2007b).

work, temperature etc. Roughly, the entropy of a system is inversely related to the quantity of useful work in the system and a system at equilibrium is one in which there is no useful work to be gotten out of the energy in the system. For example, the process in which a hot gas in a piston chamber is allowed to expand by pushing the piston is one in which work is extracted as the piston moves (the work can drive the wheels of a car) and entropy of the entire system increases as the gas expands and cools.

The fact that the second law is temporally directed and pervasive suggests the idea of connecting time's arrows to it and perhaps reducing temporal direction to entropy increase or to whatever is responsible for entropy increase. Explaining how this might work requires a capsule review of elementary mechanics and statistical mechanics.

In classical mechanics a system (say, a gas in a box) consists of particles and the state of a system at time t $\Sigma(t)$ is characterized in terms of the positions and momenta of all the particles at t. The temporal symmetry of the classical mechanical dynamical laws consists in the fact that if a sequence of states is compatible with the laws there is a temporally reversed sequence (in which the sequence of particle momenta are reversed in direction and the sequence of particle positions and the reversed momenta are temporally reversed) that is also compatible with the laws. For example, since the melting of an ice cube (i.e. the motions of particles constituting an ice cube realizing its melting) in warm water is compatible with the laws then so is the spontaneous formation of an ice cube out of warm water. The later process violates the second law since it is entropy decreasing. More generally, if an evolution of states is entropy increasing in conformity with the law then the temporally reversed evolution is entropy decreasing and also conforms to the dynamical laws. Thus, it seems that there is no possibility of grounding the second law in classical dynamics by itself since entropy decreasing evolutions of states are compatible with the laws. So the questions arise of why does entropy invariably increase over time and why is this increase apparently lawful.

The first big steps towards answering these questions were taken by Ludwig Boltzmann. The upshot of his years of investigation is this: Boltzmann characterized the thermodynamic properties of a macro system, pressure, temperature, energy, entropy, equilibrium, etc. in terms of classical mechanical quantities (position, momentum, total energy etc.) and a measure (the standard Lebesgue measure) over the set of possible states.[19] He then observed that even though there are infinitely many entropy decreasing (towards the future) micro states that realize a non-equilibrium system (e.g. an ice cube in warm water) that evolve into lower entropy states (ice cube grows bigger) such states are, in a certain sense, *rare*. The sense is that on the most natural measure the measure of the set of micro-states realizing the thermodynamic condition of an isolated non-equilibrium system that is entropy decreasing is very small. Further, the measure of the set of entropy decreasing states in small neighborhoods of typical micro states is also very small. His next step was to construe the measure as specifying a probability measure. It follows that the

[19] The entropy of a macro condition M is given by $S_B(M(X)) = k \log |\Gamma_M|$ where $|\Gamma_M|$ is the volume (on the measure) in Γ associated with the macro state M, and k is Boltzmann's constant. S_B provides a relative measure of the amount of Γ corresponding to each M. Given a partition into macro states the entropy of a micro state relative to this partition is the entropy of the macro state which it realizes.

conditional probability of a system in a non-equilibrium macro condition M being in a micro state that lies on an entropy increasing trajectory is approximately 1.[20]

A problem was soon noticed (by Loschmidt, Zermelo and others) with Boltzmann's proposal. As a consequence of the temporal symmetry of the fundamental laws the uniform probability distribution applied to a system at time t in macro condition M entails that the probability that the entropy of the system was greater at times *prior* to t also is approximately 1. Boltzmann's probability assumption entails that very likely the ice cube in an isolated Martini glass was smaller an hour ago and even earlier was entirely melted (assuming that the martini glass has been isolated during that t). More generally, Boltzmann's probability posit applied to the macro state of the universe at time t entails that it is likely that its entropy was greater at both later and earlier times. Of course this is absurd.[21] If we come upon an ice cube in a martini glass that we know has been sitting isolated in a warm room for an hour we can be certain that the ice cube did not spontaneously arise out of warm water but was previously larger. So, while on the one hand, Boltzmann's probability posit apparently accounts for entropy increasing toward the future, on the other hand, it entails the absurdity that entropy was greater in the past. This is the "reversibility paradox."

The history of statistical mechanics is littered with responses to the reversibility paradox. One response is to construe the Boltzmann probability as advice only for making predictions but refrain from using it for retrodictions. This avoids the paradox but in common with other instrumentalist proposals elsewhere in the sciences it leaves us completely in the dark as to why the prescription works.[22] This isn't the place for a survey of various other attempts to ground the second law while avoiding the paradox so I will simply describe a proposal developed by David Albert (though it has many precedents) since, in my view, it is the most promising.[23] It turns out that this proposal has profound consequences not only for the second law but also for times' other arrows.

It is generally believed on the basis of cosmological observation and theory that the state of the universe at or right after the big bang has very low entropy[24] Call the

[20] So the second law should not have been stated in the first place as an absolute prohibition on the entropy of a system decreasing but rather as being enormously unlikely.

[21] If the Boltzmann probability posit is applied to the macro condition of the universe at t since it implies that it is likely that this macro condition arose out higher entropy states and in particular this means that the "records" in books etc. likely arose out of chaos and not as accurate recording of previous events. This undermines the claim that there is evidence reported in those books that support the truth of the dynamical laws and so results in an unstable epistemological situation.

[22] Also, the prescription will prescribe incompatible probabilities at different times since the uniform distribution over the macro state at t will differ from the uniform distribution over the macro state at other times.

[23] See Sklar (1995) for a discussion of some proposals for responding to the reversibility paradox.

[24] Although there are issues concerning how to think of entropy in the very early universe it is generally held that cosmology supports the claim that right after the big bang the entropy of the universe was very tiny. This may strike one as counterintuitive since at the big bang the universe was enormously tiny and dense with matter/energy uniformly distributed in space. But because gravitation acts to clump matter this is a very low entropy condition. For a discussion see Callender (2011), Penrose (2004), Greene (2004), Carroll (2010).

very low macro state at this time M(0). Albert proposes that it is a law that there is a uniform probability distribution over the possible micro states that can realize M(0).[25] So according to Albert there are three ingredients to the fundamental theory of the world.[26]

(i) The fundamental dynamical laws.
(ii) The claim that the initial macro state is M(0) and that the entropy of M(0) is very tiny. He calls this "Past Hypothesis" (PH).
(iii) A law specifying a uniform probability over the micro states that realize M(0).[27]

These three ingredients provide a kind of probability map of the universe since they entail a probability distribution over the set of all possible micro-histories of the universe compatible with M(0). With apologies to the Coen brothers I will call the package (i), (ii), (iii) "the Mentaculus."[28]

The Mentaculus solves the reversibility paradox and explains the second law. Here is how. It follows from the Mentaculus that the probability distribution over the micro states (and histories) of a system in state M(t) is conditionalized on M(t) and *also* M(0). The measure of the set of micro states that realize M(t) on the uniform distribution that are entropy increasing in both temporal directions from t is practically 1. But conditionalizing on the very low entropy macro state M(0) excludes all but a set of tiny measure of those realizers of M(t) whose entropy increases to equilibrium toward the past. It thus blocks the argument that gave us the reversibility paradox. Further, it entails that conditional on the macro state at each moment prior to the universe reaching equilibrium it is overwhelmingly likely that entropy increases in the temporal direction away the big bang.[29]

The probabilistic version of the second law not only says that the entropy of the whole universe likely increases (or rather is likely to never decrease) as long as the universe is not yet at equilibrium but also that this holds for typical sub-systems e.g. an ice cube in a glass of warm water under a wide variety of conditions. Here is a rough "seat of the pants" argument that the Mentaculus has this consequence. Suppose that S is a small subsystem of the universe that at time t "branches off"

[25] This idea isn't original with Albert. For example, it is explicit in a lecture by Feynman (1994).

[26] While the account is developed on the assumption of a classical mechanics ontology of particles and deterministic dynamical laws pretty much the same considerations carry over to deterministic versions of quantum mechanics (e.g. Bohmian mechanics, and Everettian QM). If the dynamical laws are probabilistic (as on GRW theory) then while the initial probability distribution no longer needs to be part of the account although the past hypothesis still plays the role it plays in the account that I sketch. See Albert (2000) for a discussion.

[27] Maudlin suggested in discussion that if the uniform probability distribution accomplishes all Albert claims for it then infinitely many other distributions will do as well. This may be so. If so and if probabilities are understood objectively in the way I discuss later then there may be empirical discernable differences among these distributions or it may be a case of massive under determination. It is reasonable to posit the uniform distribution since it is the simplest until evidence is adduced against it.

[28] The name "Mentaculus" comes from the Coen brothers' movie "Serious Man" in which a character is working on "the probability map of the universe" which he calls "the Mentaculus."

[29] It is thought that the length of time it would take for entropy to increase to equilibrium is far greater that the approximately 14 billion years that have passed since the Big Bang.

from the rest of the universe to become more or less energetically isolated and that the macro state of S is m (t). We can think of the micro state of S as being selected "at random" conditional on m (t) from the macro state of the universe M(t). Since "almost all" (i.e. measure almost 1) micro states realizing M(t) are entropy increasing "almost all" of those realizing m(t) will also be entropy increasing; i.e. P(entropy S increases/m(t)&M(0)) is approximately 1. Of course this doesn't mean that it is likely that the entropy of *every* subsystem of the universe is likely to increase. Some subsystems are interacting with other parts of the universe so as make entropy decrease likely (e.g. the glass of water in the freezer). Or a system may be specially prepared so that even when it becomes isolated its entropy will very likely decrease.[30] In these cases the second law will be violated. But that is as it should be. The job is to get the second law from the Mentaculus *in so far as* the second law is correct and, arguably, the Mentaculus does that.

It may appear that the Mentaculus explanation of the second law presupposes the past/future distinction rather than explains it since it says that the big bang state which occurred 13.7 billion years or so in the past has very low entropy. But this is a mistake. The Mentaculus specifies that there is a very low entropy macro condition M(0) at the time of the big bang and no similar very low entropy condition at any other time between this event and the time the universe reaches equilibrium. The macro condition at the time of the big bang will earn its name as the "*Past* Hypothesis" if it can be shown that the other arrows of time are aligned with the entropic arrow entailed by the Mentaculus. That is, if it can be shown that the Mentaculus not only explains the second law but also explains the asymmetries of knowledge and influence, why the past seems closed and the future open etc. on the assumption that the temporal direction of the big bang is the past then it will provide a *scientific* account of the past/future distinction. Showing that this is the case is a complex project that is work in progress. Here I will just give something of an idea of how the epistemological and influence/control arrows can be grounded in the Mentaculus.

Exactly what is the epistemological arrow of time? It consists not only in the fact that we typically know and can know much more about the past then the future but also in the fact that inferences from the present to the past are grounded in a way that inferences about the future are not. For example, given the current weather conditions—clear sky, air pressure, temperature, wind etc. etc.—we can make predictions about the near term future weather; that the chance of snow tonight is less than 20%. But, we cannot make accurate meteorological predictions a few weeks or months or years from now. We can know about the weather yesterday and indeed last year and much further in the past in a quite different way and much more accurately. The clean snow on the ground provides a *record* that it snowed last night. Newspapers provide records of the weather last year and fossilized plants can be pretty good records of weather conditions millions of years ago. The epistemological asymmetry is that there are records of the past but no records to the future. The epistemological asymmetry may seem to have little to do with

[30] See Albert (2000) for a discussion of how a Maxwell demon may prepare a system so that its entropy likely decreases.

thermodynamics and the second law. But inquiring into the nature of records reveals a connection.

Consider how a thermometer produces a record of body temperature. The thermometer starts in a particular state—Albert calls this "the ready state." It interacts with a person's body (put it in his mouth) and after a few minutes produces a final state, say, mercury at the 38.6 mark. Our knowledge that this is the person's temperature depends not only on the final reading but also on our knowing that the thermometer was previously in it ready state. If the thermometer didn't start in its ready state, say the mercury was already at 40 then the final result would be inaccurate. Albert claims that all records have the feature of being grounded in an inference to the condition at a time that is between a ready and a final state. He further claims that the PH acts a kind of "mother of all ready states." The PH is incorporated in the Mentaculus and this explains why the Mentaculus grounds inferences toward one temporal direction (what we call "the past") but not toward the other.

Inferences from the current macro state based just on the uniform probability (without conditionalizing on the PH) make for good statistical mechanical predictions. Arguably, pretty much reliable predictions that about the future from what we know about the present coincides the inferences with inferences based on the uniform distribution. But, as we have seen, this does not give reasonable results about yesterday's weather and it is even worse for inferences about last year's weather. We saw that making an inference about the prior state of the ice cube in this way leads to the absurd result that the ice cube was more melted in the past. Similar reasoning applies to the question of snow and indeed anything about the past. If we applied it inferring the weather in New York 100 years ago to the date the result would be that it is likely that there was no NY 100 years ago but rather that New York has fluctuated into existence over the last 100 years. The Past Hypothesis avoids these absurd predictions about the past just as it solves the reversibility paradox. The upshot is that if we take the statistical mechanical probability distribution realistically, as we argued we should, then we need to posit the past hypothesis for those probabilities to also ground inferences from the present to the past.

I am not claiming that the Mentaculus by itself implies that any particular system's macro state is a record of any particular past events or even that our universe has systems that are records. The appearance of records may be the result of "chance" occurrences (the specific micro-state that realizes the PH). However, it is not implausible that given M(0) it is likely that as entropy increased (the universe cooled and matter clumped under the force of gravitation) the universe would evolve to contain atoms, stars, galaxies, planets, and so on. And given the macro state of the earth 3 billion years ago it is likely it would evolve to contain animal and plant life and rivers and that some animals would die and become fossilized and so on. In other words, it is very likely at points in the history (the time after the big bang) of the universe that records of various kinds would develop. To avoid a final misunderstanding, the claim is not that we explicitly employ the Mentaculus when making inferences about the past using records or when we make predictions about the future. Rather, it is that the Mentaculus provides an account of which inferences

are reliable and a scientific explanation of reliable inferences. So it turns out that there is a close connection between the second law and the epistemological asymmetry.

The arrow of influence (and the related arrow of causation) consists in the *apparent* fact that while we can exert some influence over future via our decisions we have absolutely no influence over the past. In getting a handle over how this asymmetry is explained by the Mentaculus involves distinguishing influence from control. A person controls events to the extent her intentions for such and such events to obtain influence whether such and such obtains in a normal way. I will assume that a person has *immediate control* at time t over and only over a range of decisions or actions at t. By immediate control I mean the supposed ability that one has to freely choose one among alternative decisions independently of anything else in the universe. If determinism is true then we don't really have immediate control in this sense.[31] For this reason Albert calls the supposition that we have immediate control "the myth of agency." This myth is essential to understanding how we conceive of ourselves acting and influencing other events and ultimately, I would argue, to our concept of causation. Deterministic physics can accommodate the myth of agency to an extent by supposing that what we can immediately control corresponds to alternative states of our brains that correspond to events occurring in a small region R of the brain and that in choosing a decision we are, in effect, selecting a micro history of the world. More on this in a moment.

I will say that a decision d(k) can *influence* other events, past or future, to the extent that these other events are probabilistically correlated with d(k) conditional on certain background facts. More specifically d(k) positively influences X iff $P(X/d(k)\&S) > P(X/-d(k)\&S)$ where S is the microstate of the world outside of region R. (X, d(k), and so on are used both as referring to events and to stand for the proposition that the corresponding event occurs.) A person has a *degree of control*, for example, over whether or not X or Y occurs to the extent that she can make decisions d1 = I intend that X occurs and d1 = I intend that Y occurs that influence X and Y. We will see that while the Mentaculus entails that decisions may *influence* past events we are never in a position to use or even notice this influence and for this reason it does not amount to *control* over past events. By "past event", of course, I mean events that occur between the time of the PH and the decision.

The immediate control you have over your decisions at time t is parlayed into influence over events at other times. Your decisions are correlated with future bodily movements and these with other physical events. Obviously if determinism is true then it will follow from the Mentaculus that that your decisions have influence over the past as well as the future since alternative decisions (brain events in R) will be correlated with different micro-histories of the world whose pasts and futures differ from the actual history. But the Mentaculus entails a temporal asymmetry of influence. First, notice that given the probabilities specified by the Mentaculus you

[31] Some philosophers (e.g. Kane 1996) argue that fundamental dynamical laws that are probabilistic or at least the probabilistic laws found in quantum mechanics are compatible with immediate free control. I argue that this is mistaken in Loewer (1996a, b).

will have much more influence over the future than over the past. The reason is that at t the state outside of R will typically contain records of many past events. No decision of yours now will be correlated, given S(now), whether, for example, you vacationed in Paris or London last year since photographs, other people's memories, credit card receipts, and many other records contained in S will screen off your decisions from any correlation. On the other hand, it is perfectly possible that decisions you make now about future travel are correlated with whether you will vacation in Paris or London next year. The difference in the two cases, of course, is made by the PH. Because of the PH there are can be records of past events but there are no records of the future.

The state S(t) outside of R can be counted on to contain sufficient macroscopic records to screen off decisions from most of the past. But since we are assuming that determinism is true it is inevitable that there are some past "events" that are influenced by decisions. These are plausibly very non-localized features of the microstate which are of no interest. In any case, the influence that a person's decisions have over the past falls far short of control. Of course we don't form intentions and volitions directed at past events. This is not surprising since we have no idea what past events are correlated with present conditions of our brains that might correspond to decisions. And even if we formed a past directed volition we would have no way of telling whether the volition successfully influenced a past event. Here is an example suggested by an example proposed by Elga (although not the same as his) that illustrates this. Suppose that Atlantis actually existed millennia ago but has left no localized records and further not even micro traces in S the state outside of R. So, conditional on S (the micro state outside of R) at t it is very unlikely that Atlantis existed. Further suppose the fanciful hypothesis that some of the decisions over which Adam has immediate control are correlated with whether or not Atlantis exists e.g. $P(\text{Atlantis}/S\&d(1)) > P(\text{Atlantis}/S\&d(2))$. So by deciding, say, between going to a Chinese or French restaurant for dinner Adam is "influencing" whether Atlantis existed. Of course this doesn't mean that Adam can "change the past" given what it is (tenseless "is") any more than he can change the future given what it is. Clearly Adam has no control over whether Atlantis exists even if he formed decisions (and volitions) with the contents "Atlantis exists" and "Atlantis doesn't exist" and these were correlated with Atlantis existing. Since there are no records of even traces of Atlantis there is no way of Adam telling whether his decisions have any influence. Note that it is no accident that we don't form past directed decisions since we have learned (or evolution has selected us to know) that past directed decisions are not successful in the cases in which we can check e.g. where there are records and we have no check on their success in cases where there are no external records. Of course this is not to deny that an omniscient Being who knows the Mentaculus and the micro states corresponding to S and Adam's alternative decisions could determine their influence on Atlantis. But neither Adam nor we are omniscient beings.

Much more needs to be said to show that the Mentaculus fully explains the temporal asymmetries of knowledge and control. But I think there is reason to think that the Mentaculus accounts are on the right track. If so then the "Past Hypothesis" has begun to earn its name and the Mentaculus has earned its title as a "probability map of the world."

Well, not so fast. There is a big interpretational issue facing the Mentaculus that threatens throw a wrench in the works. We have been speaking of probability distributions over micro conditions given that the dynamical laws may be deterministic. Many have thought that no genuine objective physical probabilities can coexist with deterministic dynamical laws.[32] If we can't make sense of the probabilities in the Mentaculus then the whole account collapses.

Lewis' account of laws and probabilities can come to the rescue. The fact that they do I think provides a strong reason in their favor. Recall that on the BSA the laws, including probabilistic laws, are entailed by the Best system of the world; the ideal theory that maximizes satisfaction of theoretical virtues that include simplicity, informativeness and fit. Although Lewis thought of his account as specifying dynamic chances given by indeterministic laws the account applies equally well to objective probabilities over initial conditions. It is plausible that a probability distribution over initial conditions when added to the dynamical laws may greatly contribute to informativeness at a very small cost in added complexity. In fact proposals for the dynamical laws of our world without the probability distribution are quite uninformative about macroscopic events that interest us. For example, since there are micro states compatible with the moons' current macro state (or what we know of it) on which it breaks apart the next few minutes the dynamical laws themselves together with macro information about the solar system does not entail that the moon will complete an orbit of the earth in the next month. When astronomer's make this prediction based on the dynamical laws they were implicitly ignoring these bizarre microstates. The Mentaculus explains why they are entitled to do so.

The proposal then is that the Mentaculus is the Best System of our world. By adding a probability distribution over initial conditions that conforms to the PH informativeness is greatly increased at little cost of complexity. Lewis' account of laws and probabilities thus provides a way of understanding the initial condition probabilities specified by the Albertian account (and in other deterministic theories[33]). Thus, it seems that Lewis' Humean BSA account of laws and chances and Albert's reductionist account of time's arrows are made for each other in much the same way the M-laws and M-arrows are made for each other.[34] Whether they are capable of providing an adequate account of laws and the direction of time and how they compare with Maudlin's accounts is addressed in the next section.

[32] Popper and Lewis both seem to agree that if determinism is true then there are no chances different from 0 and 1. "…if classical physics is deterministic, it must be incompatible with an objective interpretation of classical statistical mechanics" Popper, *Quantum Theory and the Schism in Physics* (Popper 1992). "To the question of how chance can be reconciled with determinism….my answer is it can't be done….There is no chance without chance. If our world is deterministic there is no chance in save chances of zero and one. Likewise if our world somehow contains deterministic enclaves, there are no chances in those enclaves". Lewis in Postscript to "A Subjectivist's Guide to Objective Chance" (Lewis 1986). In Loewer (2001) I argue that Lewis was wrong about his own account.

[33] Bohmian mechanics in non-relativisitc quantum theory also specifies initial condition probabilities and deterministic dynamics. It is plausible that Lewis' account provides the right way to construe these probabilities as well. See Loewer (2001, 2004).

[34] I am not claiming that the Mentaculus requires a Lewisian or Humean account of laws. Its truth is compatible with non-Humean accounts and even with Maudlin's account.

5 Comparisons

We have on the table two metaphysical packages that tie together views about laws, objective probabilities, and the direction of time. Maudlin's account (or my extension of it to include probabilities) posits metaphysically fundamental laws, fundamental dynamical chances, and a metaphysically fundamental arrow of time that points the direction in which the laws operate. The Lewis-Albert account reduces laws and objective probabilities to the Humean mosaic and accounts for temporal direction in terms of a scientific theory, the Mentaculus. The views obviously differ in their metaphysical commitments and their explanations. The question then is which of these a better metaphysical account of laws, probabilities and time. This is a very big and complicated question. I will only discuss a few points of comparison here and then make a few remarks about the methodology and subject matter of metaphysics.

The first and most obvious point by way of comparison is that everything fundamental in the Lewis-Albert view is also fundamental in the Maudlin view but not vice versa. M-laws and M-arrows are nowhere to be found in the Lewis-Albert account. On the other hand the patterns on which L-laws and A-arrows supervene are present in both accounts. Also, since the Mentaculus appeals only to dynamical laws, the Past Hypothesis and a probability distribution, if it correctly describes the actual world then it will also obtain even if the actual laws are M-laws and the world contains M-arrows. So the question is whether positing M-laws and M-Arrows enables explanations of the operation of laws and time's arrows that are better than the Lewis-Albert account. I will argue that they don't. To the contrary, they raise puzzling problems of their own.

But first I want to discuss some of the objections that are urged against the view that the L-laws are laws. L-laws are claimed by their detractors cannot perform the work that laws are supposed to perform in explanations, supporting counterfactuals, confirmation and so on. The core objection is that L-laws are not explanatory in the way laws are said to be. The objections that L-laws are not confirmable, that they are not confirmable, undermine induction, can't ground causation and counterfactuals and soon flow from this primary complaint. For example, Armstrong and others argue that Humean laws cannot be confirmed in the way genuine laws can be since confirmation proceeds via inference to the best explanation and Humean laws don't explain. He argues that Humean laws cannot play the role of laws in explanations as follows:

> Suppose, however, that laws are mere regularities. We are then trying to explain the fact that all observed Fs are Gs by appealing to the hypothesis that all Fs are Gs. Could this hypothesis serve as an explanation? It does not seem that it could. That all Fs are Gs is a complex state of affairs which is in part constituted by the fact that all observed Fs are Gs. 'All Fs are Gs' can even be rewritten as 'All observed Fs are Gs and all unobserved Fs are Gs'. As a result trying to explain why all observed Fs are Gs by postulating that all Fs are Gs is a case of trying to explain something by appealing to a state of affairs part of which is the thing to be explained. (1983, p. 40)

Armstrong's argument is directed against a simple regularity account but his complaint could also be made against Lewis' more sophisticated BSA. Maudlin voices a similar sentiment

> If one is a Humean, then the Humean Mosaic itself appears to admit of no further explanation. Since it is the ontological bedrock in terms of which all other existent things are to be explicated, none of these further things can really *account for* the structure of the Mosaic itself. This complaint has been long voiced, commonly as an objection to any Humean account of laws. If the laws are nothing but generic features of the Humean Mosaic, then there is a sense in which one cannot appeal to those very laws to *explain* the particular features of the Mosaic itself: the laws are what they are in virtue of the Mosaic rather than vice versa. (p. 72)

I claim that this objection rests on failing to distinguish metaphysical explanation from scientific explanation. On Lewis' account the Humean mosaic *metaphysically* determines the L-laws. It metaphysically explains (or is part of the explanation together with the characterization of a Best Theory) why specific propositions are laws. This metaphysical explanation doesn't preclude L-laws playing the usual role of laws in scientific explanations.

I don't have anything like a thorough account of metaphysical explanation (or for that matter of scientific explanation) to offer but I think it is apparent that they are different enterprises. The relevant kind of metaphysical explanation is one in which a type of fact—say mental facts—is shown to be grounded in or constituted by some other kind of fact—say neurological fact. Metaphysical explanation need not involve laws and the explanandum and explanans must be co-temporal (if the explanans is a temporal fact or property). Scientific explanation of a particular event or fact need not show that it is grounded in a more fundamental event or fact but rather, typically, shows why the event occurred in terms of prior events and laws. One further difference between metaphysical and scientific explanation is that the latter but not the former may be probabilistic. For example, the quantum mechanical explanation of why a lump of radium emits alpha particles goes by way of showing how the laws and the quantum state of the radium atoms make the emission likely. But of course, this doesn't show what the emission of alpha particles consists in. Someone who held that neurological facts make likely contemporaneous mental facts would not be offering a metaphysical explanation showing how mental facts are grounded or constituted. Scientific explanations are often involved in metaphysical explanations. For example, the metaphysical explanation that water is constituted by the H_2O molecules involves showing that H_2O molecules in certain aggregates lawfully behave as water does. And scientific explanations often appeal to metaphysical facts; for example, an explanation of why water boils at a certain temperature. But this should lead to us confusing the two kinds of explanation. Given the distinction between metaphysical and scientific explanation the argument that L-laws cannot be involved in scientific explanations of one part of the mosaic by another falls apart.

However, my defense of the distinction suggests a problem for Lewis' account of laws. One of the signal differences between scientific and metaphysical explanation

is that scientific explanations of particular events are temporally directed; prior events and laws explain subsequent events and not the reverse. It looks like Maudlin's view accounts for this asymmetry since M-laws operate on the state at t to "produce" subsequent states. The asymmetry of explanation is derived from the asymmetry of the operation of M-laws and that asymmetry is grounded in the M-arrows.

On the Lewis-Albert the temporal asymmetry of explanation, causation, and counterfactuals is grounded in the probabilistic correlations of the Mentaculus. Why do we explain the future by the past and not vice versa? The Mentaculus answers this by connecting explanation and causation to control. The idea that causation is closely connected to intervention and control is widely held.[35] There are various ways of developing this idea but they all explain the direction of causation in terms of the idea that an intervention in a system may alter the system's future but not its past. The Mentaculus accounts for this asymmetry in terms of its account of the temporal direction of control. So causation to the extent it is understood in terms of what is controlled by interventions is typically from past to future. Of course, if the dynamical laws are deterministic then the total state at t determines past states as well as future states and so no more explains the future than the past. But causation involves events that are far smaller than the total state and for them there is a deep asymmetry between correlations with future events and correlations with past events as we saw when discussing control.

I think it should be granted, even by a dyed in the wool Humean, that Maudlin's view has more of an intuitive feel about it than Humean reductionist views. We can image worlds that differ in their laws (and in their objective probabilities) but agree on their categorical facts thus violating Humean Supervenience. Further, the passage of time strikes us as something fundamental about time and not as the consequence of anything due to the probabilistic structure of the world. It seems we can imagine worlds in which time passes at least in Maudlin's sense but in which there is no increase in entropy and no probabilities. My view is that we shouldn't take such intuitions all that seriously. I won't argue for this in any depth here except to remark that it is not plausible to think that our intuitions should be reliable guide to the fundamental nature of reality.[36] The feeling of time passing and our intuitions about time are plausibly a consequence of matters like the epistemological and control arrows that may be accounted for without positing a fundamental temporal direction. Further, it is plausible that the conception of fundamental laws of physics that underlies is an amalgam of various ingredients including the 17th century conception of laws as God's commandments. The question then is whether a concept of law from which this theological element has been excised can account for the role of laws in the sciences. I have suggested here and argued in some detail in earlier papers that it can.[37]

[35] For example Woodward (2003).

[36] There is a very nice discussion of these points as regards our intuitions about time's passage in a paper by Paul (2010).

[37] In particular in Loewer (1996a, b).

Let me turn now to some problems for M-laws. Maudlin says very little about the nature of M-laws or about how they govern or produce the evolution of events. Since an M-law engages the state of a system to produce subsequent states it must in some way "recognize" a system's state; for example the momentum and positions of particles or the system's quantum state. But it is hard see what this can come to other than that an M-law has something akin to intentional or semantic structure. For example, it appears that the fundamental M-law of quantum mechanics has a structure isomorphic to the proposition expressed by Schrödinger's equation. Now the idea of our world containing at its most fundamental level intentionally structured entities strikes me as bizarre. But what is especially puzzling is the idea that this entity engages a state at t notes the direction of the M-arrow associated with that state and "produces" the next state. Never mind that there isn't a "next" state if time is continuous. The real puzzle is what "production" can be? It is not the ordinary notion of production involved when, for example, we say that an acorn produces an oak tree or his shout produced an echo. This is just ordinary garden variety causation. But an M-law together with the state at t is not the *cause* of subsequent states in this sense. One problem is that M-laws don't have location in space-time as causes do. Another is that ordinary causation itself presupposes laws connecting cause and effect. If production is a species of ordinary causation then it leads to a regress.[38] Finally, it is not at all clear how statistical mechanics fits into Maudlin's account. If probabilities are understood as degrees of propensity associated with indeterministic M-laws then there is no place of probabilities when the dynamical laws are deterministic. Perhaps Maudlin could construe statistical mechanical probabilities along Humean lines but in that case they would be "second class" probabilities and the second law would be a "second class" law.

As we saw M-laws and M-arrows are made for each other. If M-arrows were required to provide an account of the distinction between past and future then that would argue in favor of Maudlin's view about laws. So the question we need to address is how does the direction of M-arrows relate to the entropic, epistemic and influence arrows? At first one might think that the direction of the M- arrows can explain the other arrows. But on reflection it is clear that M-arrows are neither sufficient nor necessary for the entropic, epistemological, and control arrows. There are worlds in which the M-arrows points in one direction but in which the entropy gradient goes in the opposite direction. The knowledge and influence asymmetries accompany the entropic arrow and so also are not explained by the direction of M-arrows alone. So the M-arrows are not sufficient. It looks like we need a scientific explanation along the lines we sketched to account for the time's arrows even if there are M-arrows. At first sight M-arrows don't seem necessary for the temporal arrows either. There are possible worlds just like ours in their distribution of fundamental entities and properties but in which the M-arrows and M-laws are completely absent. Assuming that the Mentaculus holds in our world it will also hold in these Humean worlds. And if the explanations of the temporal arrows in terms of the Mentaculus work then the entropic, epistemic and influence arrows will also obtain in these worlds. In a world just like ours with the possible exception that

[38] Van Frassen (1989) urges an objection like this against a non-Humean account.

it lacks M-arrows it seems that entropy will likely increase in the temporal direction away from the big bang. And if we added M-arrows it seems they would make no difference to these temporal arrows even if the added M-arrows are pointing in the direction opposite the entropic arrow. It appears that in worlds matching our except possibly for lacking M-arrows there are beings like us whose knowledge and influence will exhibit the same temporal asymmetries ours do. These beings will "feel" the flow of time just as we do. And if it turns out that there are no M-arrows in our world then they *are* us. The M-arrows seem to be thoroughly irrelevant to the temporal arrows and to our experience of time.

Maudlin is aware of these objections. Here is what he says

> This response, of course, has a name: *petitio principii*. The aim of the argument it to *show* that there is no intrinsic direction to time, but only, say, an entropy gradient. But it achieves its aim only if we are convinced that the Doppelgänger has a mental state "just like ours", and the only way to make that claim even vaguely plausible is to assert that the Doppelgänger's *physical* state is not, in any significant sense, time-reversed (relative to any physically significant direction of time) at all. And that is precisely to beg the question.

Maudlin's response is that his M-arrows really are necessary for the temporal arrows. He claims that the Doppelganger doesn't have a mental state just like ours (so doesn't share our feeling that time passes) since M-arrows are necessary for sharing our brain state and specifically for our feeling of time passing. In fact Maudlin thinks that without M-arrows not only is there no experience there is no change at all. Of the world without arrows he says:

> *Nothing* happens in this world. True, there is a mapping from bits of this world to bits of our own, but (unless one already has begged the central question) the state of this world is so unlike the physical state of anything in our universe that to suppose that there are mental states at all is completely unfounded. (Even pure functionalists, who suppose that mental states can supervene on all manner of physical substrate, use temporal notions in defining the relevant functional characterizations. Even pure functionalists would discern no mental states here.) p. 143

At the bottom of Maudlin's claims is his view that laws are required for change, experience, explanation, and the rest and laws are M-laws and M-laws require M-arrows.

It should be clear that Maudlin's reply is at least as guilty of *petitio principii* as the objection to which he is replying. From a Humean perspective the claims that "nothing happens" in a world without M-arrows is completely question begging. According to a Humean an object's motion consists in its being in different positions at different times and that the direction of its motion (whether it is moving from b to c or from c to b) is determined by the entropic arrow and this direction is determined by the Mentaculus. So Maudlin's view and the Lewis-Albert view are at loggerheads. On the one side the Humean claims that she can explain change and time's arrows in terms of the Mentaculus without positing M-arrows. On the other side, while Maudlin may need to appeal to the Mentaculus to explain the arrows

from his perspective the account of time's arrows in terms of the Mentaculus already presupposes the existence of M-arrows since without them there would be no dynamical laws.

It is interesting to reflect how often fundamental disputes in metaphysics come down to each side accusing the other of "begging the question". There is some phenomena (change, consciousness, free choice) and two metaphysical positions each claiming to explain the phenomena but one side (the more metaphysically more extravagant side) claiming that the very existence of the phenomena requires her metaphysics and accuses her opponent of "begging the question" to assume otherwise. Of course, from the metaphysically less extravagant side it appears that it is her opponent who is begging the question.

6 Conclusion and some reflections on the subject matter and methodology of metaphysics

My comparison of the Lewis-Albert and the Maudlin views is far from complete. However, I think it is safe to say that at this point no argument has been produced (at least none discussed here) against either view that knocks it off the table. But the balance of the argument I think favors the Lewis-Albert position. There are a few reasons for this. First, if both views are able to explain the phenomena—the role of laws in physics and the temporal arrows—then the Lewis-Albert view does it with less ontology and so is preferable. Occam's razor has been around for a long time but it is not completely blunt. Arguments that the Lewis-Albert view is explanatorily weaker (or an explanatory failure) are, I have argued, question begging and based on intuitions that should have no authority in metaphysics. Further, it is not at all clear that M-arrows really play any role at all in grounding the entropic, epistemological, and control arrows. They earn their keep only because they are required by M-laws. The argument I presented against the need for M-arrows reflect on the need for M-laws as well.

I want to conclude with a few remarks on implications of the previous discussion of the metaphysics of laws and temporal direction for the subject matter and methodology of metaphysics. It has been argued that metaphysics has no proper subject matter of its own. An older tradition held that metaphysical problems are pseudo problems based on conceptual confusions. Once the confusions are cleared up the problems vanish. More recently it has been argued that metaphysics should confine itself to being a handmaiden to the sciences.[39] I am not sure what this amounts to but I think that it is clear that while physics (and other sciences) tell us much about what the laws and probabilities of our world are they do not say and it is not their job to say what laws and probabilities are. That is the province of metaphysics. Further, the two views about what laws are that were discussed here are genuine alternatives about the world. They are not merely notational variants

[39] This is the view of Ladyman and Ross (2007). See Paul's (2012) paper in this volume for a discussion and rebuttal of this claim.

and the two views since there are elements in the Maudlin accounts ontology that are not in the Lewis-Albert account.

Although the subject matter of metaphysics, at least concerning laws and time, is not the same as the subject matter of physics there are close connections between the methodology of physics and the methodology of metaphysics, as I pursued it in this paper. Physicists seek explanatory theories. Similarly, a metaphysical theory aims to explain. Explanation takes various forms but one is explanation by systematization. Both of the accounts discussed here attempt to systematize. Physics aims to systematize physical phenomena and the metaphysics of physics aims to systematize ontological commitments made by physics in pursuing its aim; i.e. nature of laws, chance, and so on. But while metaphysics is not merely a handmaiden of physics it should wherever possible prefer *scientific* explanations over metaphysical postulation. That I take is the upshot of my discussion of how the Mentaculus' grounds time's arrows and why that account is to be preferred to positing a primitive direction of time.

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