

MENTACULUS LAWS AND METAPHYSICS

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Abstract. The laws of nature are central to our understanding of the world. And while there is often broad agreement about the technical formulations of the laws, there can be sharp disagreement about the metaphysical nature of the laws. For instance, the Newtonian laws of nature can be stated and analyzed by appealing to a set of possible worlds. Yet, some philosophers argue the worlds are mere notational devices, while others take them to be robust, concrete entities in their own right. In this paper, I use a recent view of laws called the *Mentaculus* as a case study to illustrate the wide variety of metaphysical pictures that can accompany such a view. I conclude that the technical features of the laws — typically (though not always) given to us by practicing scientists—are compatible with many different metaphysical foundations.

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1. Introduction

Thinking about the structures and processes of the world, we take some things to be fixed — they *must* be this way — while we take other things to be contingent — they *could have been* otherwise. And it is the laws of nature that capture this distinction of necessity and contingency. If there is a *law* that massive particles attract one another, then they *must* attract one another. By contrast, if there is no law that massive particles group together in odd numbers, then they *might* or *might not* group in odd or even collections of particles. A useful and intuitive way to think about these laws of nature is to imagine other ways the world might have been. For instance, the world could have started out with particles arranged slightly differently; the meteor that killed the dinosaurs might have missed Earth; and you might have decided to have something different for breakfast. But even if the world had started with particles arranged differently, they still would have attracted one another by their masses; if the meteor missed Earth, dinosaurs still would have been subject to ecological pressures and constraints; and if you had decided to have something different for breakfast, the calories in the food would have been utilized by your body. We can imagine other



worlds with these contingent changes, yet still conforming to the same laws of nature. This, in fact, is how we do much of our counterfactual reasoning: we imagine a change to particular contingent details while holding fixed our laws of nature. And the tool that many philosophers have chosen to represent this modal structure is a set of possible worlds. But how we should think about those worlds is an open question. Are they metaphysically robust entities in their own right, or merely representational devices?

2. The Mentaculus

I turn now to *The Mentaculus*, a new way of precisely articulating the laws of nature and chances of our world. It has been developed persuasively and in a great deal of detail by David Albert (2000) and Barry Loewer (2007a; 2008; 2009). Its crucial insight relies on a connection between probabilities over microstates — the most precise specification of microphysical facts of a system (including, for example, precise positions and velocities of fundamental particles) — and the likelihood of various macrostates — the large-scale facts (including, for example, the temperature, volume, and pressure of the water in a swimming pool). The Mentaculus subsumes the possible states of swimming pools, etc., under the total state of the entire universe. Thus, all of the possible states that comprise the Mentaculus can be thought of as possible worlds and the possible states under consideration are then best thought of as parts of those possible worlds. This makes the Mentaculus an excellent case study for thinking about the metaphysical status of those worlds.

In my preferred way of stating it, the Mentaculus consists of three postulates that can be used to define a set of worlds. Each of these worlds begins in a slightly different particular *microstate* but all of them begin in the same low-entropy *macrostate*:

1. Low Entropy Initial Macrostate: Define a set of worlds that includes all and only possible configurations that begin in a macrostate of very low entropy.¹
2. Statistical Postulate: Put a probability measure over that set such that, intuitively, each possible configuration, consistent with the low entropy condition is equally likely. [Or, more precisely, since the members of the set are continuous, we'll require that the region of phase space corresponding to possible low-entropy initial conditions conforms to the uniform Lebesgue measure.]
3. Deterministic, Newtonian Microevolution: the positions and velocities of the fundamental particles evolve according to Newtonian laws.²

Thus, our set of worlds includes all possible initial low-entropy states. These different possible initial states evolve deterministically and uniquely. Some of them share our current macrostates, and some (most) of them do not, though only one

of them (our own) has our exact, actual microstate. Since this set of worlds is well defined in phase space, there are precise measures that correspond to various macrostates. For instance, consider the subset of these worlds that contain a macrostate of rolling a die. When we consider what the dice in those worlds go on to do, we can argue from plausible statistical mechanical assumptions that $\frac{1}{2}$ of them land in a macrostate of an odd number, $\frac{1}{6}$ land in a macrostate of showing five pips, etc., and almost 100% of them come from a state of lower entropy. This picture, then, yields a believable past (i.e., high probabilities for the past being the one we remember), as well as ratios for future ‘chancy’ events that match what we take their ‘objective probabilities’ to be.

David Albert describes the Mentaculus as follows:

Start (then) with the initial macrocondition of the universe. Find the probability distribution over all of the possible exact microconditions of the universe which is uniform, with respect to the standard statistical-mechanical measure, over the subset of those microconditions which is compatible with that initial macrocondition, and zero elsewhere. Evolve that distribution forward in time, by means of the exact microscopic dynamical equations of motion, so as to obtain a definite numerical assignment of probability to every formulable proposition about the physical history of the world. And call that latter assignment of probabilities the *Mentaculus*. (2015, pp.7–8)

This is an incredibly powerful picture of the laws of nature and chances. From only a few very simple assumptions, the theory yields probabilities for all future events, including those used in the special sciences, such as the chance that a particular fox population will increase, given the introduction of new rabbits. If Albert and Loewer are correct, these posits comprise the entirety of the metaphysical foundation of all of the laws of nature! Nothing more than sophisticated derivations are required to recover further scientific predictions.³ Note that these sophisticated derivations are, in fact, far too complicated for anyone to actually carry out. This is what makes the Mentaculus particularly interesting as a case study — the real value in the picture is to provide a metaphysical foundation for scientific inferences and theorizing.

When we think of the Mentaculus as a measure over an infinite number of worlds, it is reasonable to consider the metaphysical status of those worlds. Should we take them to be linguistic objects, logical objects, concrete worlds, or models? Albert and Lower prefer to think of them in Humean terms, however, I argue that there is nothing about the Mentaculus framework itself that requires this metaphysical interpretation and that broadening our view is interesting in its own right.

3. Initial and Dynamic Constraints

One of the first questions to consider is this: What counts as a possible initial state? The Mentaculus is formulated in terms of phase space, a $6n$ -dimensional space, with n equal to the total number of particles. And each point in phase space corresponds to a specific ‘way’ the universe’s particles could have started out — specifying the exact positions and velocities of every single particle. Since phase space has only six dimensions per particle, there is no way to encode for particles with different amounts of mass, or charge, or any of the other contingent properties that particles possess. Nor is there any way to allow for different numbers of initial particles. But I see no reason, in principle, that these additional features couldn’t be accounted for in a more complex phase space, so long as they remain finite (e.g., by disallowing an infinite number of particles, and disallowing an infinite range of possible particle masses, etc.) Even so, there are additional restrictions that must be stipulated. For instance, two or more particles cannot occupy the same exact initial position. Also, a single particle cannot have both a positive and a negative charge, or simultaneously have two different masses.⁴ Again, I see no reason, in principle, that these constraints could not be accommodated by the theory, broadly construed, but it is important to be clear that they are there.

How, then, should a defender of the Mentaculus go about stipulating the ‘possible initial states’? Here, we encounter the first metaphysical choice-point. If the defender has Humean sympathies, then the Mentaculus, as a way of stating the laws of nature, is nothing more than a simple and powerful way to systematize the actual pattern of events. Therefore, additional stipulations must be justified in terms of their inclusion in the best system. The Humean has to argue that allowing co-located particles into the set of ‘possible initial low-entropy states’ would lead to inaccurate, or unhelpfully complicated, or useless descriptions of the actual world. If, by contrast, the defender has anti-Humean sympathies, she is free to posit fundamental, modal facts and, likewise, is free to treat the ‘possible initial states’ as exactly that — ways the world *could have* started out. One way to do this is to note that careful, scientific observations of particles in the laboratory seem to show that (classical) particles *cannot* be co-located. Those modal facts plausibly extend to ‘possible initial states.’ It is clear to see how a difference in metaphysical approaches leads to different kinds of arguments about constraining the initial states.

Another question to consider is this: What counts as a possible evolution? We ought to block (or stipulate a low-probability for) various non-deterministic solutions to the Newtonian equations of motion. For instance, we do not want trajectories in the Mentaculus that include space invaders or Norton’s dome, since that kind of behavior violates our assumption that each initial configuration has a unique evolution.⁵ Ruling out space invaders — particles that rush in from infinity — can be ruled

out by stipulating that the particles comprising the low-entropy initial state are finite in number (something we needed to make use of the phase space already) and that they are, “all there are” in the world.⁶ Norton does present more of a problem for the theory because it is unclear how to rule them out.⁷ These amount to additional restrictions on the set of worlds allowable within the Mentaculus, but I will not consider them further since it is unclear if solutions to these Newtonian problems are likely to carry over to more realistic quantum cases.

4. Lewisian Metaphysics

Now, I would like to turn to the question of how we should think of these worlds — what kind of metaphysical things are they? David Albert and Barry Loewer are both working within a broadly Lewisian framework, so it is interesting to think about what David Lewis’s own answer to such a question might be. Lewis (1986) argues that possible worlds are concrete, but non-actual, objects. Very plausibly, some of those worlds would look just like the ones required by the Mentaculus. So, Lewis can take the Mentaculus worlds to be (merely possible) concrete entities. These possible, concrete worlds are built by recombination of perfectly natural, categorical properties. Lewis takes possible recombinations as fundamental posits that give rise to a plurality of worlds. Lewis utilizes these possible worlds in a variety of different ways. I think this picture is quite friendly to the Mentaculus machinery since the relevant worlds are simply a subset of all of these possible, concrete worlds that exist anyway. There is no additional ontological cost to identifying a subset of worlds as those that are nomologically possible and therefore, those that we use to systematize the actual events.

On the other hand, Lewis thought that the laws of nature were logical formulations — axioms in a canonical language — that systematize the actual world as simply and informatively as possible. This suggests another way of looking at the worlds of the Mentaculus: as linguistic or logical objects. Albert and Loewer endorse this second way of being Lewisian. They reject all fundamentally modal objects, including concrete possible worlds, and take the Mentaculus worlds to be nothing more than part of the simplest and most informative description of the actual world. Loewer (2007b, p.314) claims, “Like many other philosophers I don’t buy the view that possible worlds are concrete entities”. Loewer takes the laws of nature to be given by the three posits of the Mentaculus (along with a few caveats discussed below), and Loewer takes those posits to be descriptions of the actual world. Similarly, Albert claims that the Mentaculus (including the set of worlds it defines) is nothing more than a description of the actual world:

There is nothing to talk about over and above the totality of the [actual] concrete particular facts. And science is the business of producing the most

compact and informative possible *summary* of that totality. And the components of that summary are called *laws of nature*. (2015, pp.23–4)

The idea, with roots in Humean minimalism, is that *all* modal features can be wholly derived from the actual, non-modal facts. Thus, the main contribution of the Mentaculus for this kind of Humean is to provide the technical implementation of that derivation. According to this metaphysical picture, the Mentaculus worlds are nothing over and above a simple and informative description of the actual, non-modal world.

But this does not settle the question of what, metaphysically, those descriptions are. For instance, they could be actual sentence tokens, abstract sentence types, propositions, equations, fictional objects, models, or representations. And none of these options precludes further questions. For instance, if laws are sentences, and sentences are linguistic entities, then actual sentence tokens will be in a particular language (e.g., english). This view would not allow for unarticulated laws of nature. If they are abstract sentence types, they are still in a particular language (e.g., english) which is puzzling. It seems that, “gravity is inversely proportional to the square of the distance”, states the very same law as, “la gravité est inversement proportionnelle au carré de la distance”. But on such a view, they would be different laws, since they are different sentence types.

This suggests we ought to take laws to be something further removed from particular linguistic practice; something more universal — propositions, perhaps. After all, many different sentences in different languages can express the same proposition. Initially, this sounds like a promising option, particularly since the Mentaculus delineates a set of worlds and a popular view of propositions is that they are identified with sets of worlds. Note that this doesn’t yet tell us what the worlds *are*. Simply asserting that laws are propositions — and taking propositions to be sets of worlds — does nothing to provide a metaphysical foundation for the laws. Someone pursuing this option might find it helpful to turn to the large literature on the metaphysics of language for a range of views.⁸ Setting this issue aside, there is an additional problem for anyone who analyzes the laws this way: as Lewis (1983, p.367) points out, there are importantly different ways of expressing the same lawful content. There are different formulations that nevertheless all pick out the same set of worlds — many of which are intolerably gruesome. This is why Lewis thought it was so important to require that the laws be formulated in a logical language using only terms that refer to perfectly natural properties. Note that this suggestion will add more metaphysical structure to the interpretation of laws of nature — perfect naturalness — in addition to whatever metaphysical structure is required for the logical formulations.

5. Pragmatic Metaphysics

For pragmatic Humeans who think perfect naturalness adds too much metaphysics to the analysis of laws of nature, it is possible to lean more heavily on scientific practice. Loewer (2007b, p.324) argues for a *Package Deal* account on which the laws and natural properties get defined at the same time using, “simplicity, informativeness, comprehensiveness, and whatever other conditions the scientific tradition places on a final theory”.⁹ Thus, Loewer’s Humean Package Deal account requires very little by way of metaphysical structure. Plausibly, once he has told us what logical structures are, his metaphysical picture of laws needs nothing over and above the actual practice of science.

One outstanding question for Loewer’s approach is this: What counts as the target of explanation? For the Lewisian Humean, the actual world is made up of a spacetime with perfectly natural properties distributed throughout, and it is this distribution that we systematize with our logical law-statements. However, on Loewer’s account, there are no perfectly natural properties — or if there are, they may well be irrelevant to scientific theorizing. So, there is the question of what the world is made up of, fundamentally. What is meant to stand in for the ‘Humean mosaic’ that other Humeans are happy to posit? What, exactly, do our best logical law-statements—formulated in terms of useful predicates — actually systematize? Here, it may be possible to ‘give up’ on metaphysical questions altogether. It is useful to talk and reason in certain ways, and perhaps scientific inquiry ends there.

6. Representations and Models

Recall that the motivation to take the laws of nature as ‘mere descriptions’ is primarily to avoid the aforementioned commitment to ‘suspect’ metaphysical entities. I think this points to a more promising approach, still in the spirit of Humean minimalism: take the worlds to represent the actual world. Scientific representations are intentional objects that bear some relationship (e.g., similarity, one-to-one mapping, etc.) to the target phenomenon. One way that a Humean law of nature can represent the world is as a model. For instance, Newtonian, deterministic evolution yields a set of models: plug in an initial configuration and the model shows how it will evolve. Different initial configurations have different evolutions. Treating the Mentaculus worlds as models of the actual world is plausible because, typically, models show certain relationships between quantities or events by abstracting away from other quantities or events — something the Mentaculus does par excellence. By abstracting away from the actual, particular microstate and focusing on the actual macrostate, we get useful probabilities for the evolution of that macrostate.

However, there is a serious problem with treating the Mentaculus as a representation of the actual world. The procedure by which the Mentaculus produces the many probabilities (and which then can be usefully applied to actual processes) is prohibitively complicated. In theory, the Mentaculus utilizes the (unknown) actual microstate in conjunction with the (infinite) other possible microstates and evolves each of them forward in time, then takes various measures of those results. So, technically, the Mentaculus abstracts away from particular details only by accounting for *all of the actual and possible* particular details. Consider an analogy: we can represent a pool's temperature by measuring the momentum of each water molecule and then report only the average kinetic energy — we deliberately lose particular information only after we have properly accounted for it. But it is difficult to see what the point would be of engaging in such a project — why painstakingly account for every detail if it will be discarded? Worse, the Mentaculus requires not only the actual particular details of the water molecules, but also all of the *possible* particular details — at least if it is to yield probabilities for, say, temperature increase over time. And those particular details are far, far too complicated to acquire.

This highlights a serious tension within the Humean project. The Mentaculus has unprecedented predictive power, but *only insofar as* we are able to carry out the calculations — which is never. Any calculations we can perform take into account only extremely small portions of the Mentaculus. Therefore, the Mentaculus is not very useful as a scientific representation. The way in which it models actual behavior is epistemically inaccessible to us. Of course, we are free to *assume* that the Mentaculus yields a measure of $\frac{1}{2}$ for coins that land heads, but we cannot make that calculation ourselves.

The missing piece is an argument that the large-scale structure of the Mentaculus plays out in very similar ways for small subsystems and, crucially, that this can be *explained by* the structure of the Mentaculus. Thus, while it is impossible to calculate the probabilities of the entire Mentaculus, it is possible to calculate probabilities for gas in a box, or coin flips, or an asteroid ejecting a particle and changing direction, or fox and rabbit populations. But note that any explanation that goes via the Mentaculus is still prohibitively difficult to demonstrate. These considerations, then, suggest that the real power of the Mentaculus has more to do with its assumed (in-principle) compatibility with actual scientific practice and prediction than it does with useful modeling. I will argue that this is a welcome consequence on an anti-Humean interpretation.

7. Anti-Humean Metaphysics of Chance

Since Albert and Loewer, themselves, are Humeans, and since they have presented the Mentaculus as a Humean view, there is often an unstated assumption that ad-

herents of the Mentaculus have to be Humean. Of course, that isn't so. The detailed, probabilistic structure of the Mentaculus is separable from its metaphysical interpretation. Thus, we can sketch a variety of Anti-Humean versions of the Mentaculus that posit the existence of fundamental, modal entities or properties as irreducibly modal components of the Mentaculus.

As I mentioned above, an anti-Humean can take the range of possible initial states as fundamental modal facts — ways the world *could have begun*. Likewise, possible evolutions of those states could be determined modally — ways those kinds of entities *can* interact (for a dispositionalist),¹⁰ or how those entities are *governed* by the laws of nature (for DTA-style accounts).¹¹ If there are fundamental, modal facts about what kinds of particles there can be, and what those kinds of particles can do, then the Mentaculus is a way of capturing that. On a robustly anti-Humean view, the possible initial states and their likelihoods can be taken as irreducible chance-facts. In my (2016), I work out this metaphysical picture in some detail. I argue that an anti-Humean can posit an initial event that has robust metaphysical chances for all possible initial states, followed by fully deterministic, dynamical evolution:

The universe's initial chance event can be thought of as a fundamentally chancy die with an infinite number of sides tossed at the first instant, while the subsequent evolution of the universe can be thought of as a chain of deterministic dominoes — one knocks over the next, which knocks over the next, and so on. (2016, p.251)

Since we do not have access to the particular result of the universal die toss, the best we can do is update that initial probability measure on additional information as we acquire it. If the probabilistic structure of the Mentaculus is as Albert and Loewer claim, then the resulting probabilities — supposing we knew them — would be predictively useful. I conclude that in a world with fully deterministic evolution and epistemically limited agents, an initial, fundamental chance event can explain why it is rational to use these probabilities.¹²

But if, as I have argued above, the Mentaculus is much too complicated to apply to make useful predictions, the Mentaculus can still play an important metaphysical role for an anti-Humean. This is because it resolves the apparent tension between higher-level chances and lower-level determinism. To see this, note that for any particular coin flip, the total microstate, in conjunction with the deterministic microdynamics, fully determines the outcome. Nevertheless, if we assume that coins are equally likely to begin their toss in any of the microstates within a certain range, we can derive that they have a 50% chance of landing heads and a 50% chance of landing tails. But the puzzle, if the microdynamics is deterministic, is that there is no plausible way to maintain that the coin is equally likely to begin its toss in any of those initial toss-states — the coin's initial microstate is, actually, fully specified! I argue that the

resolution has to be at the very beginning of the universe, as an initial, fundamental chance event. Such an initial chance event — via the probabilistic structure of the Mentaculus — yields robust probabilities for all further events. And after that chance event, those probabilities become objective, epistemic probabilities for agents like us. They provide numbers we can use for reasoning, and can be updated as we acquire additional information (theoretically up to certainty, given full information about the microstate). Thus, the Mentaculus fits nicely with an anti-Humean account of fundamental chance and provides a metaphysical resolution to a long-standing puzzle in the chance literature.

8. Anti-Humean Metaphysics of Dynamic Evolution

One issue for a Humean interpretation of the Mentaculus is that the other worlds in the Mentaculus have different laws of nature. Albert and Loewer take the worlds of the Mentaculus to have their own laws of nature — the worlds that comprise the systematization of the actual world, themselves, are sometimes best systematized by other axioms (other Mentaculii). There are some counterintuitive consequences of this feature of the Humean Mentaculus.¹³

However, if the worlds are given an anti-Humean interpretation, then it seems plausible that all of the worlds that comprise the Mentaculus would be governed by the same laws of nature. Or, if the dispositions of the possible entities are doing the lawful work, those dispositions would be the same as in the actual world. Recall that the third posit of the Mentaculus is Deterministic, Newtonian Microevolution: the positions and velocities of the fundamental particles evolve according to Newtonian laws. We saw how this evolution can be given a Humean gloss — the temporal microevolution is best systematized by Newtonian mechanics. But of course, it can be given an anti-Humean gloss as well — the particles are *governed* by Newtonian laws of nature. Or, a dispositionalist one — the particles are disposed to exert forces on each other that are proportional to their masses and accelerations. It should be clear how a variety of anti-Humean metaphysical approaches to the dynamical laws are consistent with the broader project of the Mentaculus.

9. Conclusion

I have argued that there are many different metaphysical views that could underlie our best physics. If, as Albert and Loewer argue, we take the probabilistic structure to be given by the Mentaculus — a uniform measure over worlds, then we need a metaphysical picture according to which that structure makes sense. I have also argued that there is nothing particularly Humean about the Mentaculus — it can

play an important role for both Humeans as well as anti-Humeans — and that it might be a better fit for anti-Humean metaphysics, particularly insofar as Humeans take a pragmatic approach to the laws of nature.

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Notes

¹Of course, we will have to be more precise about what counts as a ‘possible configuration’ — something I discuss below.

²Of course, these assumptions are false because they presuppose Newtonian mechanics, rather than quantum mechanics. But similar (if more complicated) assumptions are thought to work in similar ways, with similar consequences for more complicated physics.

³This is an extremely condensed summary of the Mentaculus and its purported implications. For unfamiliar readers, further background can be found in David Albert (2000; 2015) and Barry Loewer (2007a; 2008; 2009). Important criticisms of the view can be found in Jonathan Cohen and Craig Callender (2009), Kevin Davey (2008), Heather Demarest (2016; 2017), John Earman (2006), Alison Fernandes (forthcoming), Roman Frigg (2008), Matthias Frisch (2011), Markus Schrenk (2012), David Wallace (2010; 2011), and Eric Winsberg (2004).

⁴Indeed, a move from classical to quantum mechanics may well require us to revise these constraints, since on some interpretations of quantum experiments, particles can be co-located, and can exist in superpositions of states such as charge, spin, and even *number* of particles.

⁵See John Norton (2008) for more detail.

⁶Jenann Ismael (2019) persuasively makes the case for why we need “and that’s all” clauses for determinism.

⁷For a full discussion of the problems with modifying Newtonian mechanics or ruling out domes as ‘unphysical’, see Norton (2008).

⁸See, for instance, David Lewis (1986), Robert Stalnaker (2003), Angelika Kratzer (1977), Jeff King (2007).

⁹Italics in original.

¹⁰For more, see the dispositional essentialist literature, particularly Alexander Bird (2007), Sidney Shoemaker (1998), and Stephen Mumford (2004). Note that dispositionalists who accept high-level, non-reductive dispositions, such as Nancy Cartwright (1999), will not be sympathetic to the highly reductive nature of this style of account.

¹¹For more, see the governing literature, particularly Tim Maudlin (2007).

¹²This same argument can be applied to dynamically chancy worlds as well — simply replace the ‘Humean’ probabilities in Albert’s (2000; 2015) discussion of GRW quantum evolution with metaphysically robust ‘anti-Humean’ chances.

¹³See Heather Demarest and Elizabeth Miller (manuscript) for a discussion of issues that arise for counterfactuals with the view.

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