Why Physics Can't Explain Everything

Mathias Frisch

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1. Introduction

What is it to be a law of nature? There are multiple ways in which one might categorize different answers to this question. One important division is that between Humean and non-Humean accounts of laws. According to contemporary Humean accounts the world fundamentally consists of a mosaic of non-modal particular matters of fact and nomological claims are true in virtue of the existence of certain patterns within the Humean mosaic. Non-Humean views, by contrast, postulate fundamental nomic necessities. In this paper I will focus on a particular type of Humean account of laws. Within a Humean view we can ask whether what the nomic regularities are is determined purely by properties of the Humean mosaic itself, or whether conditions of lawfulness are at least partly also a function of us, the user of the laws. That is, a second distinction is that between accounts that take criteria of lawhood to include pragmatic considerations and those that do not. To allow that the notion of law includes pragmatic elements does not entail that what it is to be a law is a function of purely personal tastes, or idiosyncratic preferences. Rather, the view I will explore here holds that laws provide us with simple and best summaries of the Humean mosaic and that considerations of simplicity and overall goodness partly reflect limitations on our cognitive capacities. Third, we can distinguish reductionist from non-reductionist accounts. According to the former, the nomic status of regularities in the higher-level sciences ultimately derives from that of the fundamental laws of physics, while the latter take the laws of the higher sciences to be autonomous.

In this paper I want to examine a particular Humean account of laws—the neo-Lewisian Best System account that has in recent years been defended by David Albert and Barry Loewer—that aims to do justice to the pragmatic idea that nomic regularities are summaries of facts about the Humean mosaic that are useful for beings like us, while at the same time being committed to reductionism and denying the explanatory autonomy of higher-level laws. Albert and Loewer's version of a Best System or Mill-Ramsey-Lewis (MRL) account of laws departs from more orthodox versions of the account by more strongly emphasizing a pragmatic dimension that arguably is

implicit already in Lewis's original account. Here I find myself in broad agreement with them. But, as I will argue here, this pragmatism is in tension with the foundationalism to which they also subscribe.

I will proceed as follows. In section 2 I will summarize Loewer and Albert's account. A crucial ingredient in a proper understanding of the status of higher science laws, according to the account, comes from the foundations of statistical physics, which Loewer and Albert take to provide the missing piece for a successful completion of David Lewis's project of a unified account of laws, causes, counterfactuals, and probabilities that is at once Humean and foundationalist. Yet in assigning neo-Boltzmannian assumptions from statistical physics a central role in their best system account of laws, Loewer and Albert have to depart from a more orthodox MRL account in a number of ways, as we will see in section 3. These departures lead to potential problems for the account, which, as I argue in section 4, can only be avoided by further emphasizing the pragmatic dimension of the account. In section 5 I argue that pragmatic considerations similar to the ones which Albert and Loewer themselves invoke suggest that the laws of the special sciences should be added as additional axioms to the Best System. Finally, in section 6 I critically examine Albert and Loewer's defense of fundamentalism against an objection due to Philip Kitcher. I here side with Kitcher and argue that the special sciences can offer explanations of the phenomena in their domain that are explanatorily independent from—and in many contexts explanatorily superior to—putative derivations of these phenomena from fundamental physics.[1]

2. From Boltzmann to Lewis

According to the neo-Boltzmannian account defended in (Albert 2000), the thermodynamic asymmetry that the entropy of a closed macroscopic system never decreases can be explained by appealing to a time-symmetric micro-dynamics and an asymmetric constraint on initial conditions. If we assume an equiprobability distribution of microstates compatible with a given macrostate of non-maximal entropy, then it can be made plausible that, intuitively, 'most' microstates will evolve into states corresponding to macrostates of higher entropy: the probability that a given macro-state evolves into one of lower entropy is extremely small. However, if the micro-dynamics governing the system is time-symmetric, then the same kind of considerations also appear to show that, with overwhelming probability, the system evolved *from* a state of higher entropy. This undesirable retrodiction can be blocked, if we conditionalize the distribution of microstates not only on the present macrostate but also on a low-entropy initial state of the system. Since the reversibility

[1] In this paper I develop further arguments made in (Frisch 2011).

objection can be raised for any time in the past after the beginning of the universe as well, we are ultimately led to postulate an extremely low-entropy state at or near the beginning of the universe and a uniform probability distribution over the physically possible initial microstates realizing that low-entropy initial state. Thus, as Richard Feynman concludes in a very readable and easily accessible presentation of this view, it is "necessary to add to the physical laws the hypothesis that in the past the universe was more ordered, in the technical sense, that it is today." (Feynman 2001, 116) This temporally "lopsided" hypothesis, Feynman says, is needed to understand and make sense of irreversibility. Albert and Loewer call Feynman's hypothesis of a low entropy initial state of the universe "the past hypothesis" (*PH*). The statistical account of the thermodynamic asymmetry, thus, has three ingredients: the dynamical microlaws (which are assumed to be deterministic), the past hypothesis *PH*, and a probability postulate (*PROB*).

Albert and Loewer maintain that this account not only provides us with the correct account of the Second Law of thermodynamics, but with the fundamental theory of the world. The three assumptions, Loewer says, provide us with a "probability map of the universe since they entail a probability distribution over the micro-histories of the universe compatible with [the initial low entropy macro-state] M(0)" (Loewer forthcoming). Adopting a term from a movie by the Coen brothers, Albert and Loewer call this statistical-mechanical theory of everything "the Mentaculus": "The Mentaculus is imperialistic since it specifies a probability distribution over all physically possible histories and hence a conditional probability over all pairs of (reasonable) macro propositions." (Loewer 2012)

What is the status of *PH* and *PROB* in the account? Feynman seems to suggest that the lopsided hypothesis about the initial state is a law. Albert and Loewer agree, offering the following three reasons for the view that *PH* and *PROB* are *lawful constraints*.[2] First, it is a desideratum that thermodynamic principles such as the "Second Law" have the status of laws (even if only probabilistic laws). Since the Second Law is, according to the *SM*-account, derived from *PROB* and *PH*, "it is absolutely essential," as Loewer says, "that *PROB* be understood as a law if it is to ground the increase of entropy as lawful." (Loewer 2008). As we will see below, this consideration is meant to extend to the laws of the special sciences more generally: what can ultimately ground the lawfulness of *all* special science laws, according to Loewer, are the dynamical laws of physics in conjunction with *PROB* and *PH* as nomic constraints.

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[2] Given he strong similarities in the views they express in print, I shall here for ease of exposition assume that the views defended in papers authored by Loewer or Albert alone also express views held by them jointly.

Second, if *PH* and *PROB* are treated as laws, they can provide a crucial missing piece in a broadly Lewisian account of counterfactuals and causation. Lewis famously attempted to derive the temporal asymmetry of counterfactuals and causation from a thesis of an asymmetry overdetermination, according to which later affairs are overdetermined by earlier ones (Lewis 1979): there are many events that have multiple determinants at a given time in their future, that is many different sets of minimally sufficient conditions for the event, but events do not similarly have multiple determinants at a given time in their past. But this thesis is false (see, e.g., Frisch 2005, ch.7). Loewer argues that if we add *PH* and *PROB* as *nomic* constraints, then we can derive the asymmetry in a non-question-begging way.

The idea, very briefly, is that we evaluate counterfactuals by calculating the probability of the consequent, conditional on the laws of the actual world, the counterfactual antecedent event *c* at some time *t*, and the actual macrostate at *t* outside of the region where *c* occurs. The asymmetry of counterfactuals is then a consequence of the fact that the laws include the time-asymmetric constraints *PH* and *PROB*. Here it is important that *PROB* and *PH* have the status of laws, for if we merely imposed a *de facto* asymmetric constraint on the past evolution of counterfactual worlds (in addition to the dynamical laws), then we would violate Lewis's desideratum of *deriving* the counterfactual asymmetry rather than merely putting it in by hand. If *PROB* and *PH* are nomic constraints, then the proper procedure for evaluating counterfactuals can be characterized in an apparently non-question-begging way as that of conditionalizing on all the laws of the actual world (which happen to include lopsided time-asymmetric constraints).[3]

The third reason for why *PH* and *PROB* have the status of laws, is that, according to Loewer, they are axioms of the Lewisian Best System. According to the MRL account of laws we should conceive of our knowledge of the world as having the structure of a deductive system consisting of a set of axioms and of all the axioms' deductive consequences. Various deductive systems may differ in their deductive strength and in their simplicity. A system's deductive strength consist in how many truths it contains, while a system's simplicity is a measure both of how many independent axioms it contains and of how syntactically simple these axioms are. Deductive strength and simplicity are competing criteria. According to the MRL account, the laws are those generalizations that are axioms of the deductive system that strikes the best balance between simplicity and strength.

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[3] For criticisms of Albert and Loewer's accounts of the causal and counterfactual asymmetries see (Frisch 2011)

3. Tweaking the System

Albert and Loewer's version of a Best System account departs from Lewis's account in three important ways. First, according to Lewis's orthodox account, all candidates for a best system state only truths. The best system is that system, among all true deductive systems, that maximizes simplicity and strength. Loewer, by contrast, does not impose truth as a necessary condition but instead proposes that the best system is the one that "best combines simplicity, informativeness and fit." (Loewer 2007, 305) That is, for Loewer, fit—that is, some measure of 'closeness to the truth'—is among those dimensions along which different systems compete and that jointly have to be maximized. Thus, the axioms of the best system might not be true, since there may be idealizations to the axioms of a deductive a system consisting only of truths that result in a sufficiently large increase in simplicity and thereby in an overall better system, even though the idealized axioms are not strictly true and the new system fits the Humean mosaic somewhat less well. Indeed, once we are allowed to trade off truth against simplicity, it is extremely plausible that the best system will not be a system of truths. We will return to this point below.

The second departure is this. Loewer maintains that *PH* and *PROB* are axioms of the best system, since adding the two conditions to the micro-dynamical laws "results in a system that is only a little less simple but is vastly more informative than is the system consisting only of the dynamical laws" (Loewer 2007, 305). That is, Loewer asks us to compare two deductive systems—one consisting *only* of the microphysical dynamical laws, and the second consisting of the dynamical laws in conjunction with two statements about the initial conditions. Thus, on Albert and Loewer's view, *all* axioms of the best deductive system qualify as laws, while for Lewis *only genuine regularities* qualify as laws. The strength of different deductive systems is evaluated by including a statement of the relevant initial conditions, according to Lewis's account, yet statements about initial conditions are not themselves candidates for being laws.

Prima facie, Lewis's account appears to track more closely the distinction between laws as dynamical equations and contingent initial conditions as providing initial data found in physics.[4] Yet the problem for allowing statements about initial conditions to be laws go beyond the question of tracking scientific practice. First, if a full statement of a system's initial conditions can be a law, then it seems to follow that in the case of very simple possible worlds a world's entire history turns out to be nomologically necessary. Consider a simple 'world' consisting of nothing but two particles orbiting each other according to Newton's gravitational theory. If we compare a deductive system

[4] Even though it is worth noting that laws in physics also sometimes provide synchronous constraints. The Maxwell equations, which imply that electric fields are not divergence-free in the presence of sources, are an example of this.

for this world consisting of Newton's laws alone (or whatever the simplest dynamical law for this world would be) with one that in addition includes a statement of the world's instantaneous state at some time, then the relative ranking of the two systems seems obvious: the initial conditions, specifying the instantaneous positions and momenta of the planets are not overly complex, since they only include a specification of the positions and momenta of the two particles, while the gain in informativeness over a system without initial conditions is quite dramatic: the dynamical laws on their own do not determine the positions or momenta of the objects at any time, but adding the initial conditions determines the entire history of the world. Thus, according to Albert and Loewer's account, the statement of the initial conditions ought to be a law of that world. But this has the consequence that the *entire* evolution of this world is nomologically necessary in that world, since the state of the world at any time is derived from the laws of the world alone. In particular, it follows that no matter what the initial conditions of the world might be, it is nomically impossible for them to have been any different.

Second, the intuition that there is some uniquely correct way in which to rank different deductive systems for worlds as complex as ours becomes increasingly strained if initial conditions are candidates for laws as well. Loewer asks us to compare a system consisting only of the dynamical laws with one consisting of laws plus some information concerning initial conditions. But how do we rank the deductive system consisting only of the dynamical laws of the actual world in comparison with one consisting of the dynamical laws in conjunction with the precise microscopic initial state of the universe? On the one hand, a statement of the complete initial conditions of the universe at one time would be extraordinarily complicated; on the other hand, the gain in informativeness is enormous: the system consisting only of the dynamical laws implies not a single particular fact about the instantiation of any properties at any spacetime point nor even any probabilities about particular matters of fact, while the system that includes a statement of the initial conditions implies the complete history of the universe. It is unclear, at least to me, how one might possibly adjudicate between the two systems and how to balance the dramatic increase in complexity against the similarly dramatic increase in informativeness.

One might reply to this last worry that this simply illustrates that in some cases facts about lawhood might be difficult to know and that the actual world might present us with such a hard case.[5] Yet, if we agree with Lewis that the criteria by which to rank deductive systems are not completely sharp, the problem is not only that the laws are difficult to *know* but that there *might not be a fact of the matter* what the laws are, once we allow initial conditions to count as well.

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[5] This reply was suggested to me by Alastair Wilson.

Moreover, Albert and Loewer not only propose a general account of lawhood, but argue that physics has discovered (at least partly) what these laws are.

One might further reply that a partial ranking of systems could be enough, as long as there is a clear winner, and the Mentaculus consisting of the dynamical laws plus a relatively simple constraint on initial conditions will rank more highly than either the dynamical laws alone (which are too weak) or a system consisting of the laws plus the precise initial micro-state (which is too complex); but is this ranking really obviously correct? It might seem obvious that adding *PH* and *PROB* to the dynamical laws dramatically increases the deductive strength of the system at only a small cost to the overall simplicity. But how do we adjudicate between the Mentaculus and a system consisting of the dynamical laws in conjunction with the precise microscopic initial state of the universe? Again, the loss in simplicity in positing the precise initial micro-state is enormous, but the increase in deductive power is also extremely large.

There is an another problem for Loewer's claim that the Mentaculus is better overall than a system consisting only of the dynamical laws: the vocabularies in which the two systems are formulated is different. This brings us to two further differences between Lewis's and Loewer's accounts. Lewis's Best System account requires that the axioms of the best system relate only fundamental properties. Albert and Loewer's account, by contrast, allows for *PROB* and *PH*, which contain terms referring to non-fundamental macro-properties, to be laws as well. Yet once we allow axioms to be formulated in different vocabularies and do not restrict our language to that of fundamental physics, the question arises how to compare deductive systems formulated in terms of different languages. As Craig Callender and Jonathan Cohen (Cohen and Callender 2009) argue, both simplicity and strength are immanent notions that are relative to an inventory of basic kinds or predicates and there exists no language- or kind-transcendent metric of comparison. Thus, *PH* is a very simple hypothesis only from the perspective of a language that includes terms referring to macro-properties but is extremely complicated from the perspective of the language of micro-physics: "If we translate the claim that entropy was low into a more fundamental microlanguage we end up with a long gruesome mess. […] The translated claim would still be strong, but hardly simple. For this reason, written in the language of the (*ex hypothesi*) fundamental kinds, the Past Hypothesis cannot be a MRL law." (Cohen and Callender 2009)

This problem can be expressed particularly vividly in terms of the following considerations due to Lewis: Consider the claim $(x)Fx$, where F is defined as holding of all and only things in the world where an arbitrary system S holds. Then F is deductively as strong as S but simpler than any system S with more than one axiom or a syntactically more complex axiom. In particular, if we take

S to be the Mentaculus, then (*x*)*Fx* seems to provide us with an even better alternative. Lewis himself responds to this trivialization problem by demanding that the predicates in which the Best System is formulated only refer to 'natural' properties or to the fundamental kinds the best system is formulated in terms of predicates that 'cut nature at its joints.'

Lewis's reply, however, appears not to be open to Albert and Loewer, at least as long as we identify the set of natural properties with the fundamental properties of physics, since their Mentaculus includes thermodynamic macro-predicates in addition to the predicates in terms of which the fundamental dynamical micro-laws are formulated. *PH*, after all, claims that the universe began its life in an extremely low entropy state.

Thus, as an alternative solution to the problem Loewer proposes that we introduce an additional dimension of simplicity along which different systems are to be compared—the *length of the derivations* required to deduce theorems—and that we award extra points to theorems that mention the motion of paradigmatic physical objects. Intuitively, the idea is that for each theorem of a system, its informativeness gets discounted by dividing it by the length of the proof of the theorem in some regimented proof system. (That is, one and the same statement will be awarded 'more points' for the condition of informativeness-plus-distance-from-the-axioms, if it is introduced as an axiom, than if it is derived from the axioms through some proof consisting of *n* steps, where $n>1$. Of course, introducing additional axioms also counts against the simplicity of the overall system.) The system consisting of the single axiom (*x*)*Fx* will then (hopefully) not come out ahead despite its simplicity, because the axiom does not mention any physical objects and the length of the derivations required to derive any theorems mentioning the motion of ordinary objects (with the help of an appropriate translation manual) would count heavily against the system.

The third and fourth departures, respectively, from the traditional MRL account are then the following: allowing the best system to be formulated at least partly in terms of non-fundamental predicates; and introducing the length of proofs required in deriving theorems as a dimension of simplicity in addition to the number and syntactic complexity of a system's axioms.

4. The Pragmatic Turn

In the last section I presented several prima facie problems for Albert and Loewer's account. I now want to show that the account has the resources to address these problems. These resources derive from a strongly pragmatic element in their metric for comparing different systems—a pragmatism that is brought out particularly vividly in their imaginary tale of how the Best System is revealed to us during an audience with God. Here is how Albert describes the scenario.

Imagine that you have an audience with God who provides you with as much information about the particular facts of the worlds as you could possible want to have. One way to provide this information is to recite long lists of particular facts concerning which properties are instantiated at which spatio-temporal locations. Yet as God begins to recite the fact,

> it begins to look as if all this is likely to drag on for a while. And you explain to God that you're actually a bit pressed for time, that this is not all you have to do today, that you are not going to be in a position to hear out the whole story. And you ask if maybe there's something meaty and pithy and helpful and informative and short that He might be able to tell you about the world which (you understand) would not amount to everything, or nearly everything, but would nonetheless still somehow amount to a lot. Something that will serve you well, or reasonably well, or as well as possible, in making your way about in the world. (Albert unpublished)

The meaty and pithy information with which God provides you, Albert and Loewer claim, consist of the micro-dynamical laws together with *PH* and *PROB*. The Mentaculus provides the best account, because it combines simplicity and strength in ways that are most useful and best *for us*.

If we emphasize that it is *our* standard of simplicity and usefulness that is the ultimate criterion by which we adjudicate between systems, both Cohen and Callender's worry and the problem of comparing systems with or without initial conditions can be answered. The yardstick for simplicity and informativeness is how practically useful a system is for us—*how well it allows us to make our way about in the world*. For beings like us the deductive system that includes the *PH* is clearly simpler—even though from the perspective of the language of the fundamental micro-theory, stating the *PH* would be a 'gruesome mess.' Thus, the problem of immanent comparisons can be answered by, first, restricting the vocabularies in which deductive systems are formulated to ones referring to those kinds in which we are interested; and, second, by stressing that any comparison between systems is with respect to the usefulness of a system for us. Both the system consisting only of the dynamical laws and that consisting of the laws and the exact initial conditions fail dramatically as far as their usefulness for us in making our way about in the world is concerned: The former system does not allow us to derive any particular goings-on in the world, not even in principle, while the latter is much too complicated to be of any practical use.

Indeed, specifying the exact initial conditions of the universe, Albert says, would violate the stipulation of providing a simple summary: "I can't tell you exactly what that [initial condition of

the universe] was" God says in Albert's story, "It's too complicated. It would take too long. It would violate your stipulations." That is, God does not offer a comparative assessment telling us that the loss of simplicity of adding the exact initial conditions of the universe would not be made up by a gain in informativeness. Instead She tells us that the exact conditions would violate a minimal condition of simplicity. Thus, practical usefulness provides not only a criterion of *relative* goodness for a system but also a *necessary* condition for being minimally acceptable: a system that includes axioms that are too complex and violate a minimal standard of simplicity is practically useless and hence could not be the Best System, no matter how informative it might be in principle or how much more informative it might be than any of its competitors.

Thus, we can distinguish two arguments for the claim that the Mentaculus provides a better system than the micro-dynamics plus microscopic initial conditions. First, a comparative argument that maintains that the Mentaculus does a better job at maximizing simplicity, deductive strength and fit than the complete micro-account. Second, one can argue that the complete micro-account fails to satisfy a minimal condition of adequacy with respect to usability, and therefore is not even a contender for the best system. The Mentaculus is better in the sense that it satisfies a necessary condition for acceptability that the complete micro-account violates. Note that if the second argument is a good one, then the first argument is not one that we humans can ever be in a position to evaluate. It would take a 'Laplacian super demon' to assess whether the huge loss in simplicity in the complete micro-account would not be more than made up for by a gain in deductive strength. While we might be able to determine that the complete micro-account would be absurdly complex, we are not in a position to assess whether the loss in simplicity is made up for by a dramatic increase in strength. Since, as Albert says, we are not in a position to hear out the whole story, we are also not in a position to assess the deductive strength of the whole story. The second argument, by contrast, is overtly pragmatic and is designed explicitly to take our human limitations into account. Since we as humans are 'pressed for time', the complete account is useless for us, no matter what its overall strength and its interest for a Laplacian demon might be.

Note that Cohen and Callender similarly appear to take simplicity not merely as a criterion of *relative* goodness but also as providing a *necessary condition* of minimal adequacy. As we have seen above, they dismiss the *PH* written in the language of the fundamental kinds as a possible MRL law, since "the translated claim would still be strong, but hardly simple." This, too, is not a comparative assessment but one appealing to a categorical criterion of minimal simplicity.

The lesson I wish to draw from our discussion so far is that the strongly pragmatic element is an essential component of Albert's and Loewer's view: without construing simplicity in terms of what is useful for beings like us, their account has no answer to the problems of comparison.

5. The Best Best System

Allowing predicates referring to thermodynamic macro-properties as part of the Best System constitutes an expansion of Lewis's original proposal, which only permits axioms containing predicates referring to fundamental properties and kinds. And as we have seen this expansion can be both motivated and defended by appealing to a strongly pragmatic construal of what it is for a system to be the best: the best system is the one that summarizes as much information about the world as possible in a way that is useful for us.

Once we have expanded the system to include thermodynamic properties, however, analogous considerations suggest that we expand the system even further: there are, it seems, systems even better than that given by the Mentaculus. According to Albert and Loewer, adding *PH* and *PROB* to the micro-dynamical laws results in a better system than adding a statement of the exact microscopic initial state, since the latter statement would be absurdly complex—too complex to be even minimally acceptable as part of any contender as overall best system. But consider now the derivation of any 'law' or regularity of the special sciences from the Mentaculus. Albert and Loewer entertain the hypothesis that all the laws of the special sciences follow from the axioms of the Mentaculus as theorems (presumably once we add an appropriate translation manual). Let us assume for the moment that this hypothesis is correct. Nevertheless, any derivation of a special science regularity from the fundamental micro-dynamics, *PH*, and *PROB* would be absurdly complicated—much too complicated to be of any help to us in making our way about in the world. By contrast, a system that contains in addition to the laws of physics also the regularities of the special sciences would be more complex along one dimension—it would contain many more axioms—but this loss in simplicity along this dimension arguably would be more than made up by a gain in simplicity along another dimension: that of the length of proofs required to derive facts governed by the special sciences.

As we have seen, Loewer himself thinks that the latter criterion contributes to the overall simplicity of a system and, indeed, the complexity of the derivations required of us seems to be as relevant to our ability to use a system to make our way about in the world as the other dimensions of simplicity are. While listening to God as She lists the complete microscopic initial state of the universe would take far too long, trying to derive anything useful concerning systems of the special

sciences from the pithy Mentaculus would likewise ask too much of our cognitive capacities. (Once we were to begin to try to derive such regularities from the Mentaculus we would quickly realize that we should not have impatiently rushed out of the room just as God began to recite higher science laws to us.)

As in the case of Albert and Loewer's argument for the Mentaculus, we can distinguish two different arguments for expanding the Mentaculus further to include special science regularities. First, if we had to rank the Mentaculus in comparison with an expanded system that included all the regularities of the special sciences as well, the latter presumably would come out ahead, since the loss of simplicity as far as the number of axioms is concerned will be more than made up for by a gain in simplicity along the length-of-proof dimension. That is, in light of the enormous gain in simplicity associated with including special science regularities in our system, these regularities count as laws just as much as the laws of fundamental physics do. This argument is closely related to an argument given by Daniel Dennett for the reality of patterns constituting macro-objects. According to Dennett, we are licensed to include such patterns in our ontology, because of their usefulness and their success in trading off reliability and accuracy of prediction against computational tractability (Dennett 1991, 36).[6] Dennett concludes from this that macro-objects are real just as more fundamental micro-objects are.

I have argued that Albert and Loewer's Mentaculus presents an unstable position: strict fundamentalism would exclude *PH* and *PROB* from the axioms of the Best System, while their pragmatic considerations push them to expand the Best System to include special sciences laws. The same conclusion can be reached by ontological considerations, paralleling Dennett's argument even more closely. Recall that one strategy for addressing the problem that comparisons of simplicity and strength are language immanent is to appeal to a privileged set of predicates referring to natural properties. On a fundamentalist conception, which seems to have been favored by Lewis, the natural properties are those at the most fundamental level of nature. But one might argue with Dennett that the set of real properties is larger than the set of fundamental properties and include scientific properties at other levels of nature as well (see also Schaffer 2004). This allows us to include thermodynamic properties in the best system, as Albert and Loewer would like, but again it is unclear why with thermodynamic properties we have reached a natural stopping point and why we the very same considerations do not push us to expand our ontology further to include properties from the higher-level sciences as well.[7] Once our ontology is rich enough, adding

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[6] See also (Wallace 2003; Ladyman et al. 2007; Ladyman, Lambert, and Wiesner).
[7] Thanks to Alastair Wilson for discussions on this point.

axioms formulated in terms of predicates referring to the scientifically rich set of properties will greatly increase the computational simplicity of our system, at very little cost to the accuracy or overall size of our axiom system.

The second argument for expanding the Mentaculus further follows Albert (or Callender and Cohen) in imposing as a minimal condition of adequacy that any deductive system has to provide us with something we can as a matter of fact use to make our way about in the world. Under this assumption the expanded system wins by default: there is ample empirical evidence that the expanded satisfies the minimal condition while the Mentaculus does not, since the derivations it requires of us far exceed our cognitive capacities. The Mentaculus, therefore, is not even a contender for the Best System.

In either case we are pushed toward a view similar to the "relativized" and anti-foundationalist Best System account defended by Craig Callender and Jonathan Cohen in (Cohen and Callender 2009; Callender and Cohen 2010). Callender and Cohen argue for a view that allows for multiple best systems, each relative to its own set of kinds or basic vocabulary. The view we have arrived at here posits a single big best system that consists of the conjunction of all of the axioms of these different systems. There may be reasons to prefer one of the two reconstructions over the other—Callender and Cohen's view stresses the independence of different sciences from one another, while the account I am suggesting here can perhaps do better justice to the common practice of constructing models drawing on the resources from multiple theories—but for current purposes the crucial point is that both views allow for the regularities of the special sciences to play the role of axioms in a best system. And it seems that Loewer would want to agree with this conclusion as well: "There is no question of using *PROB* and the dynamical laws to make predictions since we are far from being Laplacian super demons. We need the special sciences to formulate lawful regularities in macro vocabularies and to explain macro phenomena." (Loewer 2008) Since we are not Laplacian super demons, the deductive system that is best suited for us for making our way about in the world needs to include special science regularities.

Once we recognize an irreducibly pragmatic element in our standards for simplicity and strength, the Lewisian picture ought to be liberalized along another dimension: not only should the laws of the special sciences be included as axioms, but what the best axiomatization is, even within a given domain, may change in different contexts. Arguably, our pragmatic interests, even *qua* scientists, vary to some extent from context to context, and hence what the best compromise between the criteria of simplicity, strength, and fit may vary as well. Indeed, the practice of science strongly suggests that our scientific knowledge does not have a unique 'axiomatized' structure.

Thus, the Feynman has argued that physics has a "Babylonian" (as opposed to axiomatic Euclidean) structure, consisting of many interconnected and overconnected principles, without one set of statements being truly more fundamental than the rest. Rather, it is "some kind of convention" (Feynman 2001, 47), with which principles we might start as axioms (see Frisch forthcoming).

6. Against explanatory fundamentalism

In the last section I argued that Albert and Loewer's pragmatic best system account implies that the laws of the higher sciences should also be treated as axioms in a best system. And as we have just seen, to some extent Loewer seems to agree with this conclusion. Nevertheless, he and Albert afford a status to these regularities that is quite different from that afforded to them by Callender and Cohen. Overall, they argue for a reductionist view and maintain that the lawfulness of special science regularities must (in addition to any pragmatic best-systems-argument) be underwritten by the Mentaculus: "if a regularity is lawful then it must also be likely and *PROB* is the arbiter of what is likely." (Lower 2008). By contrast, for Callender and Cohen that special science laws have "a kind of metaphysical autonomy from what is going on at more fundamental levels" (Callender and Cohen 2010) is a prior constraint on any adequate account of laws. Thus, for them the fact that Albert and Loewer's account denies the autonomy of special science regularities is an argument against the account: the account is problematic precisely because "it fails to respect the autonomy of the special sciences." But why should we assume autonomy? In this section I want to examine to what extent the assumption of autonomy can be supported by arguments or at least can be given a motivation with the context of a pragmatic better best system account. In particular, I will critically examine Loewer and Albert's defense of reductionism against an argument by Philip Kitcher and offer a defense of Kitcher's anti-reductionist conclusion.

Loewer maintains that no generalization can be a law that is not a probabilistic corollary of the Mentaculus. The probability of special science laws must be close to one, otherwise they could not be laws. But this raises the worry that there are two different and on first sight independent sets of criteria for the lawhood of special science regularities: on the one hand the pragmatic Lewisian criterion, according to which any regularity is a law if it is an axiom in the pragmatically motivated Best System, which is most useful for us to make our way about in the world, and on the other hand the reductionist criterion, according to which it is a necessary condition on lawhood (and perhaps also a sufficient condition) that a generalization be a theorem of the restricted Mentaculus.

It is not clear how we should think about the relationship between these two sets of criteria. Why should we demand, once we have accepted the pragmatic Lewisian account, that all of the system's axioms can be derived from a proper subset of the axioms as theorems? Could the two sets of criteria for lawhood conflict? That is, could there be axioms of the expanded Best System that do not follow from the Mentaculus? There are two ways in which such conflicts might come about. First, the special science laws might simply be logically independent from *PH*, *PROB*, and the dynamical laws. Secondly, and perhaps more worrisome, the laws might be in conflict with the Mentaculus.

Callender and Cohen take the first possibility seriously. "There is not a shred of evidence," they maintain, "that the chances used in ecology are the ones used in statistical mechanics. A chance is relative to a particular measure over a particular state space." (Callender and Cohen 2010) Since the respective state spaces are different, the physical and ecological chances are different. Yet Loewer might reply that whatever the relevant state space for a given special science theory is, ultimately the theory must make predictions about the goings on in space and time, if it is to be empirically useful, and these predictions will either agree or disagree with those in principle derivable from the *SM*-account. Callender and Cohen insist that "surely it is implausible that every single [special science] generalization g […] is weighted heavily by Lebesgue measure when g is translated into phase space." But Loewer might respond that precisely this is a condition of adequacy for any lawful special science generalization: that its predictions concerning the goings on in space and time have high probability. Since I am not sure how to adjudicate this disagreement, I want to grant Loewer's 'imperialist' claim that the Mentaculus implies probabilities for all possible spatiotemporal macro-histories.

But why should we insist that the probabilities implied by genuinely lawful special science regularities may not diverge from those in principle implied by the Mentaculus?[8] I said that it is not obvious what the relation between the two different criteria for lawhood are to which Loewer appears to be committed. But perhaps the relation is this: laws are all the axioms of the (pragmatically motivated) best system, with the added constraint that, should the best system include a set of axioms with potentially universal scope—an 'imperialistic core theory', such as the Mentaculus—any additional domain restricted axioms (such as special science regularities) have to follow (at least approximately) as theorems from the core theory; and where the predictions of the

[8] (Meacham) argues that if probabilities may diverge, this can result in inconsistent constraints on rational belief. But Meacham's 'conflicts problem' arises only when the two chance theories at issue together with the relevant background knowledge entail each other, $TK \leftrightarrow T^*K^*$, and this condition is in general not satisfied in the case of different scientific theories.

core theory diverge from those derived from a special science regularity it is the former that should guide our credences.

But the constraint appears to be in tension with the condition that the Best System is the one that strikes the best trade-off among simplicity, strength and fit. First, since trade-offs between simplicity and fit allow departure from the truth, both as far as the axioms of the 'core theory' and as far as special science regularities are concerned, it is not clear why we should insist that there nevertheless be a tight deductive link between the core axioms and the higher-level axioms. Plausibly, domain-specific considerations of simplicity may impose demands on the axioms that prevent a tight mesh among the axioms of the kind Loewer imagines. Second, when there are conflicts between higher-level regularities and the core theory, it is not obvious why we should favor the predictions of the core theory over those of the higher-level laws. Indeed, the Lewisian criteria of lawhood suggest we weigh the predictions of the higher-level theory more heavily in cases where the predictions concern its primary domain of applications. For these axioms are designed specifically so as to strike the best balance among simplicity, strength and fit *within their restricted proper domain of application*. The axioms of the core theory, by contrast, are not chosen by considering its performance within that domain, or at least not exclusively by considering that domain. If we take our conceptual limitations seriously, the merit of the Mentaculus is assessed in light of the restricted domain consisting of those phenomena treated by physicists in statistical physics or thermodynamics. That is, even though we might insist that the Mentaculus has in principle unrestricted scope and implies probabilities for all macro-histories, the domain which is used to justify the account is that of the foundations of thermodynamics. If we wanted to insist that the Mentaculus provides us with a universal physics and imagined the axioms being chosen by a Laplacian demon, who can strike the best balance among the criteria of theory choice for the entire Humean mosaic, then the domain of a higher-level science is a proper subset of that of the Mentaculus. But even the Laplacian demon could discover that the domain specific theory does a better job within the very domain for which it is designed at balancing the criteria within its domain—or at least that it does no worse job than the Mentaculus, which has to strike a balance between simplicity and fit across many different domains.[9]

Thus, I believe that the demand that higher-level laws be probabilistic correlates of the Mentaculus does not sit well with the overall pragmatic outlook of Loewer's and Albert's Lewisian account. It is a demand that requires the powers of a Laplacian demon to assess; and it is in tension with the idea that the best system need not be true and that fit is one of the dimensions, alongside

[9] (Weslake forthcoming) makes a similar argument. See also (Dennett 1991, 47–8).

simplicity and strength, that we aim to maximize. Nevertheless in what follows I want to grant Loewer that higher level laws are theorems in the Mentaculus. Even then higher-level laws possess an *explanatory* independence from the Mentaculus, as I want to argue now.

Both Loewer (2008) and Albert (unpublished) use an anti-reductionist argument by Philip Kitcher as foil to defend their own reductionist account. Kitcher contrasts R. A. Fisher's evolutionary explanation of a regularity discovered by Arbuthnot—that in each of the 82 years from 1623 onward the preponderance of children born in London were boys—with a microphysical derivation of the sex of every child and maintains that even if *per impossibile* we possessed a micro-physical derivation of the sex of each child, starting with the microscopic initial state of the world at each copulation, this derivation would not advance our understanding of the sex-ratio and would not show that Arbuthnot's regularity is anything but a gigantic coincidence (Kitcher 2001). For a Laplacian demon, as Loewer describes the argument, Arbuthnot's regularity would "appear to be a gigantic coincidence, since the initial micro conditions that result in a majority of male births have nothing physically salient in common. […] Kitcher takes this to show that there is a lacuna in the physical laws that is filled by Fisher's law." (Loewer 2008) This lacuna, both Loewer and Albert argue, is filled by the Mentaculus. If we assume that account—that is, if we start with an equi-probability distribution over all initial microstates of the universe compatible with *PH*, evolve that distribution forward until the beginning of Arbuthnot's observation period in accord with the (assumed to be) deterministic micro-laws, and conditionalize this on the existence of the solar system and on everything else taken for granted in the discussion of relative birth rates in London—then the resulting conditional probability distribution should be exactly in accord with the predictions based on Fisher's evolutionary explanation. If Fisher's explanation is correct, then, so Albert, the probabilities to which this explanation appeals must follow from the true and complete physics. Thus, Fisher's explanation provides us with some information about the "true and complete and universal physical theory", but it could not possibly add to that theory.

I here want to side with Kitcher. In fact, there is a puzzle as to what exactly the lacuna left by a putative microphysical derivation could be, such that it can be filled by the Mentaculus. Loewer says that *PROB* fills any explanatory lacunae by showing that Fisher's law is likely "and *PROB* is the arbiter of what is likely:" "All special science regularities and all causal relations can be obtained by conditionalization from the Mentaculus". (Loewer 2012) But if all it took for the reductionist account to show that Fisher's law was *likely*, then the microscopic derivation Kitcher imagines would leave no lacunae, for that account shows not merely that Fisher's law is likely, given the initial state, but that it follows *deterministically* and with probability one from that state.

Perhaps then what *PROB* adds is that it renders Fisher's regularity lawful. The problem with the Laplacian derivation Kitcher imagines is, one might think, that it derives Fisher's regularity from purely contingent initial conditions. *PROB*, by contrast, is a law on Loewer and Albert's account and hence the contribution of the Mentaculus might be that it can underwrite the nomic status of Fisher's regularity. But Fisher's law depends for its holding on facts about the Solar System and conditions on Earth that made the evolution of biological systems possible. Plausibly many special science regularities have extremely low probability conditional merely on an initial Big Bang macrostate and attain a high probability only once they are conditionalized on events resulting in the formation of our Solar System and the evolution of life on Earth, which themselves have extremely low probability conditional on the initial Big Bang macro state. But then the Mentaculus derives special sciences regularities from a combination of laws and contingent conditions, just as the microphysical derivation, which Kitcher rejects, does.[10] Indeed, the fact that Fisher's regularity is rendered likely by the Mentaculus only conditional on later macro-states has the consequence that the Mentaculus faces the same explanatory gap that concerns Kitcher.

The problem for the Mentaculus is that there are myriad such conditional probability distributions, each conditionalizing on different macro-facts, and the Mentaculus alone does not allow us to single out one over the other as particularly illuminating. Moreover, Fisher's account involves idealizations and abstractions and what is taken for granted as background conditions in the account is left to some extent vague. Thus, arguably none of the conditional probability distributions that might be in principle recoverable from the Mentaculus will match the probability distribution derived by Fisher *exactly*. Finally, in order to derive the sex-ratios of different species at different times the putative Mentaculus would have to conditionalize on different features of the macrostate at different times—macrostates that will be similar in countless ways and will differ from one another in countless others. All this raises the worry that even if we were to grant Albert and Loewer that the Mentaculus allowed in principle derivations of probability distributions for sex ratios, the simple account given by Fisher relating birth ratios to sex ratios at maturity (and unifying the probability distributions for different times and species) would be deeply buried within the Mentaculus. Fisher's account does not merely give us an observation about a particular probability distribution that follows from the Mentaculus, as Albert suggests, but gives us an argument why it is *this* conditional probability distribution, rather than one of the many others

[10] One might think that the lawful claim underwritten by the Mentaculus is that Fisher's regularity has a very high probability conditional on the occurrence of certain contingent events. But the microphysical derivation similarly implies such a conditional law: that Fisher's regularity holds with probability one conditional on the contingent initial state.

implied by the Mentaculus that is useful and interesting for us. Only from the perspective of evolutionary biology and its way of 'carving up the world' can we readily detect those conditional probability distributions that are relatively simple and informative about sex ratios at birth. What Fisher's account adds, then, is a reason for focusing on certain conditional probability distributions rather than others—it provides us with reasons for us to expect that certain specific conditional probability distributions among the very large number of such distributions in principle implied by the Mentaculus are particularly simple and useful for beings like us to make our way about in the world.

Consider a gerrymandered set *S* of events all of which have probability *P*=0.53—the probability of having a boy, according to Fisher's account—conditional on some relatively localized macrostate of the world, such as the state of London in 1623. One would expect there to be a very large number of such events, including, for example the probability that a certain not entirely symmetrical coin comes up heads, say. Now compare the Mentaculus-account of the events in *S* with a Mentaculus-account of the events in the set *B* of male births. The events in both *S* and *B* have negligible probability given just *PH* and *PROB* but all have the same probability *P* conditional on certain later macrostates. Indeed from the perspective of the micro-physical theory the two accounts are equivalent: both proceed by evolving the initial probability distribution forward in time and then conditionalizing on a later macrostates and showing that all events in the two sets have conditional probability *P*. Nevertheless, it seems intuitively that the fact that all the events in the gerrymandered set *S* have probability *P* is a mere coincidence, while the fact that all male births have probability *P* is not: in some intuitive sense, the probabilities of the events in *S*, unlike those of the events in *B*, have nothing to do with one another.

This intuition, I want to suggest, can be cashed out in terms of the existence of unifying theories: the events in *B* can be unified *at the macro-level* in terms of the evolutionary account while the events in *S* cannot be similarly unified.[11] The evolutionary account provides an explanation of the probabilities for the events in *B* that is both simple and unified. By contrast, by assumption no such simple unified explanation of the events in *S* is possible. Of course, the Mentaculus unifies the phenomena as well—if successful it provides the ultimate unified account of the world—but it only provides us with conditional probabilities of events on the complete micro-physical goings-on entire 'slices' of the world, rather than singling out certain higher-level structural features that may account for the phenomena we are interested in. Note also that the events in *S* aren't

[11] (Weslake forthcoming) suggests, after similar arguments to the ones I presented here, that Fisher's explanation is superior because of its greater abstraction.

spatiotemporally more unified: it is easy to pick a set of events *B* such that the macro-state on which we have to conditionalize is spatiotemporally much more localized than the respective macrostate in the case of male births. From the perspective of the micro-level both sets of events simply follow from facts about the to-ing and fro-ing of the microscopic particles. By contrast, Fisher's explanation points to certain higher-level structural features of evolutionary systems which are alone relevant for a derivation of the sex ratio, abstracting from additional microscopic details irrelevant to that phenomenon.

Thus, if we assume, as seems plausible, that it contributes to the goodness of an explanation if it does not add irrelevant details and explicitly singles out the factors explanatorily relevant in a given context, then Fisher's explanation is explanatorily superior to the putative explanation posited by Albert. The evolutionary account shows that Arbuthnot's regularity holds no matter what the microphysical details as long as they allow for the existence of evolutionary systems. The point here is not merely that these details would be absurdly complex and hence would violate Albert's minimal condition of adequacy, but that it is a virtue of an explanation if it accounts for its explanandum only by appealing to genuinely relevant features of the system at issue.

Albert and Loewer's Mentaculus account of higher-science laws faces the same explanatory gap as the putative microphysical derivation imagined by Kitcher. Just as "the initial micro-conditions that result in a majority of male births have nothing physically salient in common" (Loewer 2008), the different thermodynamic macrostates on which we have to conditionalize to get Fisher's law have nothing physically salient in common. Thus, Albert and Loewer face a dilemma: either they have to deny that a microphysical derivation would leave an explanatory gap, or they would have to concede that the Mentaculus fails to close the gap.

One might nevertheless have the intuition that the micro-physical account is in some sense deeper since any higher-order regularities are ultimately 'due to' the fundamental laws. The fundamental laws, one might want to say, are what are ultimately responsible for the existence of the higher level laws, and it is in this sense that Fisher's account does not add anything. But this reply is not open to a Humean. All there is ultimately, for Humeans, is the mosaic of particular matters of fact. The role of the laws, at all levels, is to provide us with particularly useful ways of summarizing features of that mosaic, and there is no genuine sense for the Humean in which higher-level laws are the product of lower-level laws. Lower-level laws might be privileged in the sense that they are supposed to be universal, at least in principle. But as we saw above, it does not follow from this that they are likely to fit phenomena within a certain higher-level science better than the higher-level laws specifically designed for that domain.

There are myriad patterns that the Humean mosaic exhibits. Which of these patterns are privileged? The pragmatic answer that Albert and Loewer give to this question is that the only sense in which certain regularities describing the mosaic might be privileged is that they are regularities useful for us in making our way about in the world. I find this answer very compelling. Yet I have argued in this paper that it is incompatible with the explanatory reductionism that Albert and Loewer also defend.

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