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How Can We Explain Time-Asymmetric Processes?

A Critical Analysis of David Albert and Barry Loewer's Mentaculus Theory

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Abstract

There are plenty of irreversible thermodynamic and causal macroscopic processes, yet the fundamental physical laws are completely time-symmetric. How can this be explained? In my paper, I will analyse David Albert and Barry Loewer's theory, which claims that only the distribution of matter in the universe is fundamental. They defend the "Best System Account" for laws, by which these are the strongest and simplest systematisation of scientific truths but have no modal force, i.e. they are a true description of the mosaic but do not necessitate any part of it. Albert and Loewer believe there are three main elements of these laws, which they call the Mentaculus: the fundamental laws of dynamics, the "Past Hypothesis" that the entropy was very small at the Big Bang and a uniform probability distribution over all possible states at the beginning of the universe. I will address four main questions: Why should there be a uniform probability distribution over all possible states at the beginning of the universe (as is postulated by the Mentaculus theory)? How can this theory explain the thermodynamic behaviour of isolated systems? Can all laws be reduced to the few principles of the Mentaculus? Is it even possible to develop laws that fulfil the requirements of the Best System Account?

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1. Introduction and physical background

In our surrounding macroscopic world, we experience many time-asymmetric phenomena, so-called irreversible processes. These can be understood intuitively as the following: if they were to be filmed and then watched in rewind, it would be easy to distinguish the "past to future" sequence from the "future to past" sequence. If an egg falls down and bursts apart, it will never recompose itself spontaneously. If a drop of red ink is diluted in a water basin, the drop will not form itself once again at any point. An example of a reversible process would be shooting two billiard balls at each other - the film and its time-reversal cannot be told apart. They will of course show different movements, but it will be impossible to know which one goes "from past to future" and which one goes "from future to past".

Reversible and irreversible processes are described by Thermodynamics, whose 2nd Law states that, for any isolated system, the entropy will always increase or remain the same (if it is in an equilibrium). Entropy can be conceived as a measure for the typicality of the distribution of entities in a system. For example, when ink is dropped into a glass of water, all ink particles are grouped in one small region of the glass, a very untypical distribution that has low entropy. Over time, the ink particles will diffuse until they reach a very typical state in which they are uniformly distributed throughout the water. This process of moving from an untypical towards a typical state constitutes an increase in entropy. It goes on until an equilibrium has been reached, from which point on the entropy will remain constant. Mathematically, entropy can be characterised by the Boltzmann equation $S = k \cdot \ln(W)$, where S is the entropy and W the number of distinct microscopic states available to the system given the macroscopic constraints (k being a constant named the Boltzmann constant in honour of its discoverer). This characteristic of thermodynamic behaviour shows that there is an intrinsic asymmetry in our macroscopic laws that has to be explained in some way. It should be noted that the 2nd Law of Thermodynamics is a statistical law, i.e. that entropy decreasing states are in fact not impossible, but merely highly improbable. Taking the example of the drop of ink once again: there is a probability (that can be calculated) that the atoms of the ink form a single drop some time after diffusion, but it is so small that it will never be observed.

As the behaviour of macroscopic systems is believed to supervene on the microscopic laws that rule its elementary components, we would expect the latter to reflect the same asymmetry. However, the fundamental laws of physics are time-invariant, i.e. for every physically allowable sequence of events, the inverse sequence of time-reversed states is also allowable. Whether it is Newton's laws or Schrödinger's equation, both are symmetric regarding time. The Standard Model of particle physics recognises the so-called CPT-symmetry: it says that any physical object is invariant under a simultaneous transformation of charge, parity and time. A universe in which all matter is replaced by antimatter (corresponding to a charge inversion), all objects have their positions reflected by an arbitrary plane (corresponding to a parity inversion) and all momenta are reversed (corresponding to a time inversion) would be a "mirror image" of our own and would be subject to the exact same physical laws. It is only this combined symmetry that is valid, not time inversion alone, though. In fact, the decay of the neutral kaon (one of the particles the Standard Model predicts) breaks the time-symmetry and is thus a microscopic irreversible reaction. This kaon decay could be a microscopic explanation for time-asymmetry but it is a very rare reaction and not involved in any of the known macroscopic irreversible processes. It is a further hint at the existence of an intrinsic time-asymmetry rather than an explanation of it. Thus, the fundamental physical laws do not seem sufficient to explain irreversible processes.

Another possible source of explanation could be the time formalism that underlies our physical laws. The Theory of Special Relativity postulates the four-dimensional Minkowski space-time, in which time is considered a dimension similar to the three spatial dimensions. This is another drawback as spatial dimensions are completely symmetric - there are no irreversible processes in space. If an object is moved across space, its movement can't be distinguished from that of an object that has the exact inverse movement. However, the Theory of Special Relativity establishes that nothing can travel faster than the speed of light, thus limiting the space-time regions with which interaction is possible. These regions are called light-cones. Minkowski space-time is orientable, i.e. we can distinguish those light cones from which a given object can receive information from those to which it can send information. These could be identified respectively as "past" and "future" light cones, but nothing in the formalism compels us to do so. Our experience of irreversible processes is thus compatible with the mathematical formalism of space-time, which is a first necessary feature but not sufficient to explain time-asymmetry.

If we come back to Boltzmann's definition of entropy, a further problem arises. The mathematical formalism of entropy knows no objective distinction of past and future. In fact, if we started "retrodicting" the past from our present state, we would reach the conclusion that entropy will increase towards the past in exactly the same way as we predict it to increase towards the future. Thus, if we look at a cube of ice in the sun, we will predict that it will melt (increasing entropy towards the future), but at the same time we must posit that it was created spontaneously out of melted water (increasing entropy towards the past). Boltzmann's definition entails that entropy was greater both in the past and in the future, which is absurd since it would mean that every present moment is an entropy maximum in the history of the universe. This could be understood if the universe was at equilibrium and the entropy would remain at an equal level throughout time, but no experimental findings suggest this is the case. This effect is called the "reversibility paradox" and is precisely due to the fact that fundamental physical laws are time-symmetric and have no intrinsic distinction of future and past. In practice, no one tries to "retrodict" what will happen, because there are accounts of the past and not of the future. If a meteorologist was to "retrodict" the weather of yesterday, no one would listen to him because everyone knows how the weather was yesterday. This asymmetry of records and why "retrodicting" the past makes no sense will also have to be addressed by any theory that wishes to explain irreversible processes.

2. The Humean reductionist ontology in the conception of David Albert and Barry Loewer

Barry Loewer's paper "Two accounts of law and time" and David Albert's book *Time and Chance* present a Humean reductionist ontology in the footsteps of David Lewis. They claim that only the distribution of properties through space-time is a fundamental ontological entity. In this section, I will outline this ontology and its conception of time, laws and causation.

Humean metaphysics receives its name from the 18th century Scottish philosopher David Hume who was the first to "eschew fundamental nomological modalities",[2] denying that there are any necessary connections in nature. Contemporary Humean reductionists hold that "the totality of the universe consists

[2] Loewer (2012), p. 116.

of the distribution of fundamental categorical properties / quantities and relations instantiated by fundamental entities (particles, fields, etc.) throughout all of space-time", which they call the "Humean mosaic".[3] This means that the only fundamental truth of the world is the distribution of properties throughout space-time, the only thing an omniscient being would need to fully characterise our universe. This distribution is determined in past, present and future. Loewer thus defends a so-called block universe view, a term coined by Huw Price as "regarding reality as a single entity of which time is an ingredient, rather than as a changeable reality set in time"[4]. In this block, there is a space-time distribution of properties that is fully determined at the beginning of the universe. The change that we experience comes from moving across this distribution, no new states are produced at any time.

Therefore, physical laws are no ontological primitives for Loewer - they are explained instead by Lewis's Best System Account (BSA). This Best System is the scientific systematisation of fundamental truths that best combines "simplicity and strength".[5] It is the set of true propositions that best renders the regularities of the Humean mosaic, explaining the most features with the least complex foundation. These L-laws (as Loewer calls them in acknowledgement of Lewis's role in their development) explain regularities among the Humean mosaic and thus depend on the distribution of fundamental facts in the mosaic. However, they are no mere instruments to help us navigate through our surroundings: Lewis, Albert and Loewer stress that the BSA is the *true* account of the regularities of the Humean Mosaic.

According to Albert and Loewer, L-laws can be either deterministic or probabilistic. This is surprising at first, since Loewer stresses at the same time that the Humean Mosaic is deterministic. Yet, probabilistic descriptions can be much more informative while losing insignificant simplicity compared to a deterministic theory. An example of that would be the theory of radioactive decay - it is a fundamental fact about the Humean mosaic when precisely a certain particle will decay, but in absence of that knowledge a probabilistic theory explains the statistical behaviour of numerous particles best.

[3] Loewer (2012), p. 116.
[4] Price (1996), pp. 12-13.
[5] Lewis (1994), p. 478.

David Albert spells out what the ingredients of such a BSA theory of the world are according to him (and to Loewer):

I. The fundamental dynamic 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 the "Past Hypothesis".

III. The Statistical Postulate specifying a uniform probability over the micro states that realise M(0).[6]

"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)"; Loewer calls it the "Mentaculus".[7] It explains how our universe has evolved from the big bang until now. It started as a macrostate of low entropy M(0) with all compatible micro states having equal probability. All later states have to be compatible with the Past Hypothesis and its low-entropy postulate - this allows Albert and Loewer to avoid the reversibility paradox. A state is for Loewer the position and momenta of all elements of the Humean mosaic at a given time[8], The fundamental laws then explain the regularities of the Humean mosaic.

Speaking of "initial state" and "past" requires an account of the passage of time. Loewer believes that time passes, but not that there is a fundamental arrow of time. He thinks that the arrow can be reduced to other phenomena, for which the entropy gradient seems most promising.[9] The 2nd Law of Thermodynamics postulates that for an isolated system (what we suppose our universe to be) the entropy statistically increases or remains the same (if it is in an equilibrium). As our universe is not in an equilibrium for all we can tell, the entropy gradient of the universe as a whole always points in the same direction, which Albert and Loewer define as the future.[10]

Therefore, the only fundamental entity of the Humean reductionist account is the Humean mosaic, the distribution of properties in space-time. Laws explain how these properties change, but have no modal strength, i.e. they do not have any influence on the mosaic. Time passes, but its arrow can be reduced to the entropy gradient and causation is conceived as counterfactual dependency. In the next

6 Albert (2000), p. 96.
7 Loewer (2012), p. 124.
8 Loewer (2012), p. 122.
9 Loewer (2012), p. 121.
10 cf. Loewer (2012), p. 126.

sections, I will address several problematic issues of the Mentaculus and the Best System Account in general.

3. Criticisms of the Mentaculus

In the following, I will analyse the Mentaculus as a proposal for a Best System Account (BSA) more closely and discuss several of its postulates that I find inaccurate. In 3.1, I will argue that there is little reason to suppose a uniform probability over the micro states realising M(0), in 3.2 that the Past Hypothesis fails to explain changes in entropy in isolated systems and in 3.3 that a reduction of all laws to the Mentaculus is implausible.

3.1. Why assume a uniform probability over the micro states that realise M(0) at the beginning of the universe?

One of the main objectives of the Mentaculus is to give an account of how fundamental probabilities can be compatible with a deterministic Humean mosaic. Albert explains this by claiming that the Fundamental Postulate of Statistical Physics holds at the beginning of the universe.[11] This Statistical Postulate states that for an isolated system with an exactly known energy and exactly known composition, the system can be found with equal probability in any micro state consistent with that determination.[12] This is viewed as the axiomatic foundation of the three thermodynamic ensembles and forms the basis of any statistical mechanics calculation. Being a fundamental postulate, it cannot be explained by anything else; but the powerful and intuitively evident principle of indifference justifies it. The principle states that in absence of any further knowledge, we can assign equal probabilities to every compatible situation.

Albert holds that the Statistical Postulate is valid only in the beginning of the universe, at which point the Mentaculus is determined for the rest of its duration. In chapter 4 of his book *Time and Change*, he motivates this as follows. If we looked at the physical state of the universe ten minutes ago and assumed the Statistical Postulate to be correct, we could convincingly explain and predict how our universe evolved from this state to its present state with increasing entropy. However, if we

[11] Albert (2000), p. 85.
[12] Tolman (1938), pp. 59-61.

tried to "retrodict" from the state ten minutes ago to the beginning of the universe, we would face the reversibility paradox highlighted in the introduction. Albert's strategy is that, if we want to eliminate the reversibility paradox, we have to move our point of reference so far back in the past that no "retrodiction" is possible, so essentially to the big bang.[13] Therefore, by establishing that the Statistical Postulate holds at the beginning of the universe and no other point, he manages to introduce objective probabilities compatible with a deterministic Humean mosaic and at the same time circumvents the reversibility paradox.

I will bring forward three arguments against this view. Firstly, it is doubtful that the beginning of the universe would satisfy the condition for application of the Statistical Postulate. Secondly, it remains unclear what exactly the postulated probabilities are supposed to be. Thirdly, one can question why Albert chooses a uniform probability distribution as it is the one that fits the actual single micro state worst.

There are still many open questions as to how exactly our universe came into existence, but it is generally assumed that the big bang was a space-time singularity. Yet, in order to be applicable, the Statistical Postulate requires a system to have an exactly known energy and exactly known composition, a criterion that our current knowledge of the beginning of the universe can definitely not satisfy. Unfortunately, Albert does not address this issue as assuming the Statistical Postulate at the big bang seems to be unproblematic for him. One option that Albert could pursue is to justify the use of the Statistical Postulate because it fits our calculations and can accommodate fundamental probabilities with the Humean mosaic and eliminate the reversibility paradox. But Albert refuses to introduce any kind of epistemic justification as he does not think that our knowledge (or rather lack of knowledge) of the Humean mosaic should be of any relevance to its best system of laws,[14] so this does not seem a viable option. Loewer is more subtle on that point, suggesting to apply the Statistical Postulate not necessarily at the precise beginning of the universe, but "soon after"[15]. The term is vague, but for our purposes we assume Loewer means by "soon after" a time at which the composition and energy of the universe can be known precisely enough to apply the Statistical Postulate. However, this brings us back to the problem of "retrodiction" between this "beginning of the

[13] Albert (2000), pp. 93-96
[14] Albert (2000), p. 64.
[15] Loewer (2007), p. 311.

Mentaculus" and the actual beginning of the universe. As Albert argues, if we consider anything other than the "entirety of the universe at nothing later than its beginning", we fall back into our reversibility paradox.[16] An option to circumvent this issue might be to define "soon after" as a limit but the implications of this would have to be analysed in further details. Another path could be to argue that the meaning of entropy in the context of the very early universe is unclear in itself. The reversibility paradox might then not be problem, but how this should exactly work remains an open question.

Independently of the external conditions for the Statistical Postulate that might not be fulfilled, it also remains unclear how exactly Albert & Loewer want to define their probability distribution. According to them, the initial probabilities are objective attributions of chances of a microstate at the beginning of the universe. This is the only time when there are probabilities, since once the microstate is fixed, the Humean mosaic unfolds and determines every subsequent state.[17] Frigg & Hoefer point out that "postulating a probability distribution for […] the only probabilistic event ever seems conceptually problematic".[18] As there is nothing chancy about the initial condition, the distribution seems only to reflect our ignorance of the system's actual micro-condition[19]. However, Albert refuses any kind of epistemic probabilities, claiming that it is absurd that behaviours of actual physical systems should in any way be explained by our judgments.[20] Yet, relative frequencies or propensities are also not an option as there is only one actual macro condition and the beginning of the universe is the only probabilistic event ever. The argument of Albert and Loewer seems to be that these objective probabilities are a fundamental feature of the world that cannot be explained any further, but this does not clarify at all of what the probabilities actually are.

The fact that there is only one actual microstate brings up a further problem: any other probability distribution than a uniform one will fit the real situation better. The best fit would be provided by a Dirac-distribution peaked at the actual microstate, so this would be much more informative at equal simplicity and should

[16] Albert (2000), p. 85.
[17] Loewer (2007), p. 316
[18] Frigg & Hoefer (2013), pp. 570-571.
[19] Frigg (2008), p. 679
[20] Albert (2000), pp. 64-65.

be favoured by a BSA account of laws.[21] Unfortunately, Albert and Loewer don't explicitly argue for why they prefer the uniform probability distribution over other distributions. It would be the distribution that the principle of indifference would commend for epistemic probabilities, but Albert and Loewer refuse this interpretation outright.

Therefore, the supposition that the Statistical Postulate holds at the beginning of the universe is constructed on an uncertain basis. The condition that the energy and composition is known does not apply at the beginning of the universe so there is no reason for it to hold. Furthermore, it is unclear how Albert and Loewer define their probabilities and why they choose a uniform distribution.

3.2. Can the Mentaculus explain the behaviour of energetically quasi-isolated sub-systems of the universe?

David Albert avoids the "reversibility paradox" in his *Time and Change* by positing that the Statistical Postulate only holds at the beginning of the universe and everything else unfolds through the fundamental laws. He believes that this, together with the Past Hypothesis, suffices to explain all changes in the Humean mosaic. In this section, I will discuss a criticism made by Eric Winsberg in his paper "Can conditioning on the "Past Hypothesis" militate against the reversibility objections?", namely that Albert's theory cannot avoid the "reversibility paradox" in small quasi-isolated sub-systems.

In order to illustrate this, we look at a Coleman cooler filled with lukewarm water in which we put a block of ice. The cooler with the water is in interaction with the rest of the universe until a certain point in time S, when the ice is added and the lid of the cooler is closed. The system is now energetically isolated from the rest of the universe and we expect the ice to melt slowly and the water to cool down until a state of equilibrium is reached where all ice is molten and the water has a uniform temperature (that will lie at some point between 0°C and the initial water temperature). The final temperature will depend on the initial masses of ice and water as well as the water's initial temperature; the entropy of the system will increase until the equilibrium is reached from when on it remains constant. This is a reaction that has been observed over and over again and that is well understood and described by physical laws. If it is to be accepted as a Best System Account, the

[21] Frigg (2008), pp. 678-679.

Mentaculus must be able to explain the thermodynamic behaviour of this quasi-isolated sub-system.

How can the Mentaculus account for this? Unfortunately, neither Albert nor Loewer discuss this example, but Winsberg outlines an argument that seems plausible. First of all, the Past Hypothesis only counts for the universe of the whole and cannot be applied to this sub-system that is extremely small in comparison to the size and age of the universe. Yet, it must be assumed that this small system behaves in the same way as the universe as a whole for the Mentaculus to be able to explain its thermodynamic behaviour. There is no purely mathematical reason to do so - the entropy of the cooler could go as wild as it wants, it would never have any influence on the entropy development of the universe as a whole because of its negligible size. Therefore, Albert must postulate that any subset of the universe (including those that are isolated) has a uniform probability distribution like the universe as a whole.[22] At first sight, this seems plausible: after all, why should any sub-system behave significantly different from the universe in total if the same laws apply? Even if there is no way to prove this postulate, we might be willing to accept it nonetheless.

However, if we refer to the cooler once again, at some time after it has been closed but before it has reached equilibrium (some ice has molten and the temperature of the water has decreased, but both water and ice still coexist), a problem arises. At this moment (as at any other moment), the cooler has to be in a microstate compatible with the past hypothesis, i. e. that its entropy was small at the beginning of the universe. The problem is that this poses no constraint at all on our sub-system (except if it had been isolated since the beginning of the universe, which is typically not the case for Coleman coolers). Its entropy is so small in comparison with that of the whole universe that it is impossible for any state of the cooler to be in conflict with the Past Hypothesis. This would mean that if we look at our cooler in an intermediary state (some ice has already molten, but some is still there) it would be highly probable that the entropy increases both towards the past and the future - we are back at our initial reversibility paradox. Clearly, the Past Hypothesis at the beginning of the universe is not sufficient to explain the thermodynamic behaviour of small quasi-isolated systems because their influence on the entropy of the whole universe is utterly negligible.

[22] Winsberg,(2004a), pp. 500-501.

One answer to this objection would be to postulate that the Past Hypothesis and the Statistical Postulate hold not only at the beginning of the universe but also in any quasi-isolated system at the moment it is separated from external influences. This so-called branch system is advocated by Eric Winsberg in his paper "Laws and Statistics"[23] but was developed earlier by Hans Reichenbach and Paul Davies.[24] It would eliminate the reversibility paradox and allow us to explain the thermodynamic behaviour of quasi-isolated systems. However, Albert explicitly rejects this strategy for two different reasons. On the one hand, he thinks it "sheer madness" to try to determine what exactly constitutes the quasi-isolated system (the content of the cooler, the cooler and its content, the room in which the cooler is, …) and which is the precise moment it enters isolation - that knowledge is necessary in order to determine when to apply the Past Hypothesis. On the other hand, he thinks it unnecessary and illegitimate to assume the Statistical Postulate at other times than the beginning of the universe.[25] The second point is rejected by our example of the Coleman cooler as it is clearly not sufficient to postulate the Past Hypothesis at the beginning of the universe.

The first objection is to be taken seriously, though: Davies characterises branch systems as "regions of the world which separate off from the main environment and exist thereafter as quasi-isolated systems"[26]. Basically, these are systems that separate energetically from the universe at some point to become independent (and usually merge again with the rest of the universe at some later point) and have their own Past Hypothesis at the moment of separation. This is problematic if we consider that both Albert and Loewer's objective is to reduce the arrow of time to the arrow of entropy: this branch system would entail that each separate branch has its own time system that is created upon separation. In fact, Lawrence Sklar points out in his book *Physics and Chance* that the branch theory only works under the assumption that all systems are exhibiting time evolution in the same direction.[27] Winsberg does not even attempt to counter the argument, claiming that his goal is not to provide "an explanation of the origin of asymmetries in time" but only to "explain how time-symmetric micro laws can be compatible with time-asymmetric macro laws", acknowledging that he can "readily admit that we are

[23] Winsberg (2004b), pp. 709-712.
[24] cf. Reichenbach (1956) and Davies (1977) for their proposals of branch systems
[25] Albert (2000), pp. 88-89.
[26] Davies (1977), p. 69.
[27] Sklar (1993), p. 328.

helping ourselves to some other arrow that is already out there".[28] Winsberg makes no comment about what this arrow might be, except that it might be related to the causal structure. This is incompatible with Albert and Loewer's proposal that the arrow of time can be reduced to the gradient of entropy.

Thus, the Mentaculus faces an important obstacle. It cannot explain the thermodynamic behaviour of quasi-isolated systems because it has no way to get rid of the reversibility paradox in these systems. The branch system offers a possible solution but requires an independent arrow of time, making it at odds with what Loewer and Albert specific projects.

3.3. Is the reduction of all laws on the Mentaculus plausible?

The Humean Reductionist ontology defended by Albert and Loewer claims that the Mentaculus and it alone is the Best System Account (BSA) of laws of the universe. In this section I will argue that while the Mentaculus should definitely be part of the BSA, a much stronger and informative system can be achieved if other non-fundamental laws are included in it. Albert and Loewer defend a strong reductionist position: they claim that all laws and regularities that we observe can be inferred deductively from the fundamental physical laws. I will tackle this position and try to explain why non-fundamental laws cannot be reduced to the Mentaculus but should still be included in the BSA.

In our scientific practice, postulating the existence of laws is by no means a prerogative of physics - both other natural sciences and social sciences claim to discover laws that reign their respective fields. Reducing all these laws to one physical "theory of everything" is a long standing hope, but until now there are few hints that we might be successful in that enterprise one day. The most prominent example is probably mental states, which many have tried to reduce to brain states of neuroscience - until now to no avail. Similarly, while it is obvious that the laws of genetics for example have a certain connection to fundamental physical laws (they definitely obey them) they have never been proven to follow deductively from them. Maybe one day scientists will achieve that reduction or maybe they will prove it is impossible, but for now the evidence is too scarce to postulate that every scientific law follows from the Mentaculus.

[28] Winsberg (2004b), p. 711.

So, if non-fundamental laws cannot be deduced from the Mentaculus, should they be included in the BSA? In order to judge this, we have to take a closer look at the criteria of evaluation. Lewis essentially points out two features that have to be weighed against each other: simplicity and informativeness.[29] These are vague concepts, but it seems intuitively clear: we want a theory that can explain as many phenomena as possible while keeping the number of postulated entities and the complexity of the calculations to a minimum. Adding non-fundamental laws decreases the system's simplicity but that is compensated by the superior informativeness. If we look at the spectrum of scientific research nowadays, plenty of research is done in the field of non-fundamental laws; every special science develops its own set of laws. It seems that a cluster of different BSAs for each science would reflect best how research is actually done. This is a promising approach: by restricting every system to its domain of application, we can ensure that it is most simple and informative for this particular science.

Frigg & Hoefer present another objection that must be dealt with: most of the laws of biology are limited to what happens on planet earth and those of medicine and the social sciences even to what happens to human beings. Would it not be preposterous to include laws about things that are confined to a minuscule part of the universe?[30] Frigg & Hoefer's answer to this objection is twofold. Firstly, they emphasise that a system's strength is determined not only by the number of tokens covered but also by the number of types. If these non-fundamental laws can explain biological features that would otherwise be inaccessible, the number of types the system explains is increased significantly. Secondly, the BSA was developed to be a "guide to life for epistemically limited agents",[31] so it is normal that the focus would be on the space-time regions of the universe that concern us directly. While the first is plausible, the second is highly contentious and would definitely not be supported by Albert and Loewer - I will discuss it in detail in section 4.

In summary, the Mentaculus provides a basis for a BSA but can by no means be a complete account: deducing all non-fundamental laws from the Mentaculus remains out of reach for the moment and non-fundamental laws are needed to explain many features of the world around us. Ignoring them would make the system considerably less informative.

[29] Lewis (1994), p. 478
[30] Frigg & Hoefer (2013), pp. 564-565.
[31] Frigg & Hoefer (2013), pp. 567-568

In section 3, I have presented several of the challenges the Mentaculus has to overcome, as well as answers of some other Humean reductionists, although quite a few of them would be incompatible with Albert and Loewer's conception. In the next section, I will point out issues of the Best System Account in general and why it might be impossible to find laws that can meet its standards.

4. Can there be laws that fulfil the requirements of the Best System Account?

The Best System Account (BSA) has the difficult task of working with laws that have no modal force but should have more strength than mere instruments. On the one hand, Humean reductionists believe the only fundamental ontological entity is the Humean mosaic and that laws only identify regularities in the mosaic but do not influence the latter in any way. On the other hand, they stress that the laws are a systematisation of fundamental truths and not only instruments we use in order to make experimental predictions. Without looking at the specificities of the Mentaculus, I will outline why finding this middle ground might be an impossible task.

It is an important issue that we only have access to a certain part of the Humean mosaic, namely the one that is in our past light cone, but the Best System Account is to be applied to the entire mosaic. The task of the BSA is thus to find the most simple and informative systematisation of truths about something to which it has only partial access. This is a difficult task by itself, but in addition to it we have absolutely no reason to suppose the Humean mosaic outside of our past light cone should behave in the same way as the one we know. After all, the laws have no influence whatsoever on the composition of the mosaic. If we are instrumentalists, this is not a problem: we only want laws to predict the outcome of our experiments, so the fact that they might not be valid in space-time regions we have no access to is irrelevant. If it is the laws that produce future states there is now problem either, because by definition the states will have to be compatible with the laws. That does not mean we might not believe in the wrong laws, but if we get them right, we are safe. For the BSA, which wants to be on a middle ground, neither of the two strategies work. So it seems an overly ambitious project to want to identify the best systematisation for the whole Humean mosaic while only having access to one part of it.

Frigg & Hoefer point out a second issue in their paper "Best Humean System for Statistical Mechanics": it is possible that our universe will "have an infinitely long future "heat death" state in which, basically, nothing happens". That is one of many scenarios envisaged by astrophysicists, and for such a universe the Best System would be something like "nothing happens but minor quantum fluctuations in an otherwise cold, dead, slowly expanding space". However, this kind of BSA would be of no avail at all to our scientific research, which naturally concentrates on what surrounds us. The two authors thus reject the argument by claiming that the BSA should be a "guide to life for epistemically limited agents - agents for whom […] one corner of the Humean mosaic is going to be more relevant and important than the vast regions with which they have no contact".[32] It is true that laws are only relevant for epistemically limited agents - after all omniscient beings could know the entire Humean mosaic. Yet, the postulate that the BSA is a "guide to life" should not be made light-heartedly, especially if like in our case it is in direct conflict with the other two virtues, simplicity and informativeness. This would change the BSA's scope from being the "best scientific systematisation of the totality of fundamental truths of the world",[33] to be the best scientific systematisation of the truths that we have access to and that are relevant for us. It is obvious that we can't know anything about the parts of the Humean mosaic we have no access to. However, claiming that the scope of the laws is to guide us goes pretty far down the road of instrumentalism. After all, the only difference that would remain is that a BSA has some claim to truth, but if relevance for us becomes a main criterion for the choice laws, that is an important blow to the strength of that claim as well. Anyway, it is extremely doubtful that Albert and Loewer would agree to Frigg & Hoefer's proposal as they refuse any justification for the Mentaculus based on our limited knowledge. Albert describes the suggestion that the probabilities of the Mentaculus might be of epistemic nature as "insane"[34] because he sees no reason why our knowledge (or rather lack of knowledge) of the Humean mosaic should be of any relevance to its best system of laws - he would most definitely present the same argument against any "guide-to-life-BSA". Yet, they don't give any hints to how they would respond to the "heat-death" argument.

[32] Frigg & Hoefer (2013), p. 564-565.
[33] Loewer (2012), p. 119.
[34] Albert (2000), p. 64.

The Best System Account is thus in a difficult position: it has to find an explanation of laws that have no modal force but are more than just instruments to predict the outcome of experiments. These laws further have to be the best systematisation of a Humean mosaic we only know partially. Frigg & Hoefer suggest including a third criterion of evaluation for a best system, namely that it helps explain the questions with which we are confronted. This view, however, leans strongly towards instrumentalism and would be refused by Albert and Loewer.

5. Conclusion

In this paper, I have pointed out several problematic issues of the Mentaculus: using the Statistical Postulate at the beginning of the universe, the explanation of small, isolated systems and the attempt to reduce all laws on the Mentaculus. Furthermore, I pointed out the difficulty for the Best System Account to develop laws that satisfy its criteria but are neither mere instruments nor have a modal force. I hope the outlined issues can be of use in the further development of theories to achieve a better explanation of time-asymmetric processes.

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