Is the Mentaculus the Best System of Our World?

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Abstract

Barry Loewer and David Albert put forward a theory that they call "*The Mentaculus*", which they claim to be "arguably a complete scientific theory of the universe". Albert and Loewer's Mentaculus is an expanded version of their version of statistical mechanics. On their view - as recently updated by Loewer's "*Package Deal Approach*" - The Mentaculus is the "best system" of our world in the Lewis-style sense of this term: it contains a partial description of the fundamental reality ("The Humean base") and provides the optimal balance between informativeness and simplicity. The Mentaculus has other advantages, in particular, it is reductionist in the sense that it unifies all the sciences, and it is physicalist in the sense that the account of everything is ultimately based on physics. In this paper we examine the extent to which The Mentaculus is reductionist and physicalist. We compare it with "*Flat Physicalism*", which is our version of expanded statistical mechanics, that is a reductive type-type physicalist identity theory of everything that there is. The Mentaculus is less reductionist than Flat Physicalism, since whereas both theories assume the fundamental microdynamics and suitable contingent facts, The Mentaculus assumes the Past Hypothesis and a Statistical Postulate, that Flat Physicalism derives from the microdynamics and the contingent facts. Additionally, Flat Physicalism derives from the latter all the special sciences kinds and laws, while The Mentaculus does not contain any explanatory account of such reduction. Therefore, Flat Physicalism is arguably "better" than The Mentaculus in the "best system" sense of the term.

1. The Mentaculus

Barry Loewer and David Albert put forward an "outrageously ambitious" theory that they call "*The Mentaculus*", which they claim to be "arguably a complete scientific theory of the universe" (Loewer 2020a).

> "The Mentaculus is a probability map of the universe in that it determines a probability density over the set of physically possible trajectories of microstates emanating from M(0), and thereby probabilities over all physically specifiable macro histories. Once the dynamical laws are specified, The Mentaculus contains an answer to every question of the form "What is the objective probability of B given A?" for all physically specifiable propositions A and B. For example, it specifies the probability that an ice cube will

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completely melt in the next five minutes given a description of the macrostate of its environment, and the probability that Trump will be impeached given the current macrostate of the universe." (Loewer 2020a, p. 6)

A central motivation of Loewer and Albert for endorsing The Mentaculus is that they think it forms the "best system", in the Lewis-style sense of this term: it is a partial description of the fundamental reality ("The Humean base", discussed below) which provides the optimal balance between informativeness and simplicity. It seems that on their view this "best system" has also other advantages, in particular, it is *reductive* in the sense that it unifies all the sciences, and *physicalist* in the sense that the account of everything is ultimately based on physics.

In this paper we show that The Mentaculus is not the "best system" since a "better" theory is possible and available: our "Flat Physicalism" theory, described in Section 2, which is more reductive and more physicalist than The Mentaculus, and therefore offers a better balance of simplicity and informativeness. The Mentaculus can be improved along its lines, in a way that is compatible with Loewer's Package Deal Approach (2020b), but in this case the distinction between the Humean framework and reductive physicalism becomes less clear. We compare the two theories in Sections 3 and 4.

The Mentaculus is essentially a version of statistical mechanics, *expanded* and *augmented* so as to account for all the phenomena. "Statistical mechanics" was originally the name of the (ongoing, unfinished) project of accounting for the facts described by thermodynamics, on the basis of the fundamental theories of physics together with some auxiliary hypotheses. Various theories share this name as well as this aim, but differ in the details of how to achieve it.[1] Here is Albert and Loewer's theory of statistical mechanics, which is at the heart of The Mentaculus:

> "The Newtonian statistical-mechanical contraption for making inferences about the world consists, in its entirety, of three laws and one contingent empirical fact. The empirical fact is the one about what the macrocondition of the world currently happens to be (or rather, the empirical fact is the one about what the directly surveyable condition of the world currently happens to be; where the directly surveyable condition of the world - insofar as Mr. X is concerned - includes its macrocondition plus whatever, perhaps microscopic, features of Mr. X's brain he may happen to have direct and unproblematic introspective access to)[2], and the laws are:
> 1. The Newtonian law of motion (which is that F = ma).

[1] The standard ones are described in (Frigg 2008).

[2] Since here "introspection" must be a measurement of a system by itself (not one part of the system measuring another part, but one and the same part measuring itself), we are not sure that this can be part of a physicalist account of the universe. This detail of The Mentaculus can be amended by opting for a type-type reductive account of the mental, as in Flat Physicalism, described in Section 2.

2. The Past-Hypothesis (which is that the world first came into being in whatever particular low-entropy highly condensed big-bang sort of macrocondition it is that the normal inferential procedures of cosmology will eventually present to us).

3. The Statistical Postulate (which is that the right probability-distribution to use for making inferences about the past and the future is the one that's uniform, on the standard measure, over those regions of phase space which are compatible with whatever other information - either in the form of laws or in the form of contingent empirical facts - we happen to have)." (Albert 2000, p. 96)

(For brevity, we use the following acronyms: NM for Newtonian mechanics, CF for the contingent fact, PH for the past hypothesis, SP for the statistical postulate. We stress that CF is - as Albert writes - what the *macroscopic* condition of the world currently happens to be, as is *surveyable* by a given observer, and includes this observer's brain state which is[3] this observer's perceptions and memories.)

We will argue that our Flat Physicalism is "better" than The Mentaculus in that it retains the same degree of informativeness, but is simpler. In this paper as a working hypothesis, we adopt the Humean framework of the Lewis-Loewer-Albert best system approach to laws (as in Loewer 2020b; Albert 2014; see Sec. 3 for a detailed discussion of this framework). Famously, there are various ideas about what simplicity is, which lead to different "measures of simplicity". Here we shall not dwell on this notion, because we will show that Albert and Lower assume (implicitly or explicitly) all the laws and facts that we assume, namely CF+NM, but add some other laws, namely the PH+SP.[4] It seems to us that Albert and Loewer can arrive at their additional laws either in our way, namely by deriving PH+SP from CF+NM (see below, what we mean by "deriving" here), in which case their Mentaculus will be improved in the sense that it will simpler.; or they must commit themselves to an extra source of information concerning these additional laws, and this extra source will make their system much more complex. By "derivation" of PH+SP from CF+NM we allow various kinds of inductive inferences from CF. We describe the derivation of SP in Sec. 2.3, and of PH in sec. 2.4.

The system we call Flat Physicalism holds that all there is to the world is its actual microscopic trajectory as given by the specific equation of motion of the physical theory (quantum or classical, which includes all the parameters and boundary or initial conditions). In a Humean framework we take the micro-trajectory to be the *full* Humean base, where the laws of physics are supposed to give a partial simple and informative description of this base. It seems to us that this is also Albert and Loewer's view[5] (we discuss their Humean view in Sec. 3). Everything that is true about the world should be derived (see below) from facts we know to be true about the micro-trajectory and

[3] Or on which supervenes; we don't address this difference here.
[4] We thank Barry Loewer and David Albert for discussions about this and other points in this paper.
[5] Personal communication.

nothing else. That is, Flat Physicalism assumes NM and CF only, and we will show that it can derive from them PH (*if* it is true; see Hemmo and Shenker 2012 Ch. 10 and 2019a) and SP (*if* it is true; see Hemmo and Shenker 2019b and below). This version of statistical mechanics is part of a reductive type-identity physicalist theory (see Hemmo and Shenker 2019a, 2019b, 2020, Shenker 2017a, which builds on Hemmo and Shenker 2012, 2016, Shenker 2017b,c, 2020).

In order to be "arguably a complete scientific theory of the universe", both systems, Flat Physicalism and The Mentaculus, must account not only for thermodynamics but also for all the (other) so-called special sciences. According to Flat Physicalism, since all there is to the world is the full micro-trajectory, Laplace's demon who knows the actual trajectory ipso facto knows all the special sciences laws and facts. However, in contemporary literature, most authors with physicalist inclination endorse so-called "non-reductive physicalism", that is: a view that allows for "multiple realizability" of special sciences kinds by physical kinds. Only a minority of thinkers endorse "reductive physicalism" and do not accept multiple realizability. Flat Physicalism is a full-fledged reductive type-identity theory, and therefore it rejects multiple realizability (and multiple realization, of course). We are not sure about Albert's and Loewer's current views on this matter: if they accept "multiple realizability" (as Lewis did), their metaphysics is not physicalist, but dualist. We will argue for this claim as we proceed and present what we take to be their views on this matter in Section 4.

A dualist metaphysics might be the "best system", but still it is of interest to know that this is the view endorsed. If so, we shall argue that Flat Physicalism is "better" in this context too, since it is physicalist, and moreover it accounts for the special sciences on the basis of CF+NM alone, thus retaining the informativeness of The Mentaculus in a simpler way.

In the above description of The Mentaculus (as well as in Flat Physicalism as we discuss it here), classical mechanics plays the role of fundamental physics. Of course, according to contemporary physics classical mechanics is false. Still, it is useful to consider statistical mechanics in the classical context because arguably the classical theory preserves some of the salient explanatory and predictive aspects of the true fundamental physics, under the appropriate relevant conditions[6] (see Wallace 2001, Sec. 1; Ladyman and Ross 2007, Ch. 1, for a critical discussion of the use of outdated physics in philosophical discussions; see Shenker 2020 on the foundations of quantum statistical mechanics).

Let us describe already here what we take to be the crucial points of disagreement between Flat Physicalism and The Mentaculus approaches.

[6] In this paper we do not address Hempel's Dilemma concerning what is the physics that ought to be taken as fundamental in a reductionist project; see (Firt, Hemmo, and Shenker 2020).

Both Flat Physicalism and The Mentaculus agree (we think) that we have available to us, as empirical data, the observations CF as described above: the macroscopic condition of the world as it is given to an observer. The two theories differ on the following.

Flat Physicalism takes CF as a starting point, although it is open to the possibility that its contents is false.[7] Suppose first that CF is by and large true: what is it true *of*? The answer to this question should be given by a theory about the world, which provides an explanation for CF. One good candidate for an explanation of CF is that the world is as described by NM. (In Flat Physicalism as well as - we think - in the The Mentaculus PDA approach, NM is a placeholder for our best contemporary theories of physics.[8]) In particular, this means that the best explanation of CF is that everything that there is in the world is its micro-trajectory in the sense of NM, of which CF+NM provide a partial description (CF provides only some of the parameters and initial and boundary conditions that are needed to provide a well-defined micro-trajectory, and therefore it is compatible with a *set* of such trajectories, only one of which is the actual one). According to Flat Physicalism, given CF+NM we can derive PH and SP (as described in Section 2 below), since both PH and SP are partial descriptions of the actual micro-trajectory, that are more partial (and therefore compatible with) the partial description provided by CF+NM. PH is understood here as some macroscopic description of the state of the world at some past moment, and is *in this sense* on a par with the contents of CF (but contains *less* information than CF+NM); and SP is understood as expressing relative frequencies along the actual micro trajectory of the universe (and *not* as pertaining to counterfactual histories). Finally, there is no guarantee that CF is true: it may be that CF is false (we think that talking about the likelihood of its being true is circular, if meaningful at all).[9] It may even be that the best theories that explain the experience of CF are those that tell us that it is false to a larger or smaller extent. Why do we often adhere in practice to the option that CF is true? It is perhaps a more convenient choice, but it is not compelling. (Contemporary brain science gives good reasons to think that a substantial part of CF is false.)

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[7] We focus here on the case in which CF is true, because it is the simplest way to present our main point. But importantly we are not committed to CF being true about the world or even to its being highly likely true. Theories of physics (and of special sciences which reduce to physics) are constructed so as to explain CF, but explaining CF does not mean vindicating CF as true about the world. Our scientific theories may or may not entail a correspondence between the content of CF and reality. It may turn out that the best explanation for the data of CF is that its contents are partly false; contemporary science gives us good reasons to think that this is the case (see Shenker 2020c). We do not think that this result is catastrophic - unlike Albert, as we point out below. On an even more skeptical view concerning the status of the CF data, see also (Shenker 2020b).

[8] See (Firt, Hemmo, Shenker 2020) on Hempel's dilemma.

[9] It is circular because it requires postulating a probability measure (or a typicality measure) over counterfactual states, where the *choice* of measure, according to which the truth of CF is highly probable, if it is empirical at all and not given to us by some external source of information (see below), is determined by the facts along the *actual* micro-trajectory, described by CF itself (see our 2012, Ch. 8; 2015b).

In The Mentaculus, by contrast, the truth of CF has a much stronger status: the laws of nature are selected so as to guarantee its likelihood, given some understanding (which Flat Physicalism rejects) of what counterfactuals are and what probability in physics is (see some details in Albert 2000, 2014; Hemmo and Shenker 2012, 2015, 2016). The crucial difference between the two approaches is this. In Flat Physicalism the schema is CF → NM → PH+SP; where CF may not be true. in The Mentaculus, the schema is NM+PH+SP → CF (with high probability), so that CF is likely to be true, and this avoids the "skeptical catastrophe" (Albert 2000), In our view, although a world in which NM+PH+SP obtains is nice and comforting in that - if you accept the right notions of counterfactuals and probability - your experience and memories are likely to be true, this argument provides a less simple system, which can be appreciated considering the following questions: why are NM+PH+SP accepted as part of the "best system" in The Mentaculus; and what kind of *support* do we have for postulating them? One option is that the truth of NM+PH+SP is *tested* empirically via its prediction of CF: it is in this sense that this theory is *empirical*. In this option The Mentaculus relies on CF to the *same* degree that Flat Physicalism does, and then the degree of simplicity is the same as in Flat Physicalism. But since The Mentaculus wants something *stronger*, something that will guarantee *high probability* for the truth of CF, it needs to give PH+SP a status that is *stronger* than that of CF, that is: *independent* of CF. But what is the source of PH+SP? Where does this stronger support come from? We think that this source is over and above physics and adds substantial complexity to the metaphysics of The Mentaculus.

In what follows we shall not expand on this theme of what explains what. Instead, in this paper we describe Flat Physicalism and go into some details in comparing it with The Mentaculus. The paper is structured as follows. In Section 2 we describe Flat Physicalism, and in the following sections we compare it with The Mentaculus. Readers who are familiar with Flat Physicalism, or who are interested in first seeing in what sense we think Flat Physicalism is "better" (in the sense of "best system") than The Mentaculus, may skip Section 2 and return to it later. Section 2 is partitioned into subsections for ease of reference or of returning. We describe the basic ontology of this theory (Sec. 2.1 and 2.2); how probability arises and how to derive SP (if true) even when the underlying micro-trajectory is deterministic (Sec, 2.3); the status of the PH and how to derive it (if it is true) (Sec. 2.4); what it takes to reduce the special sciences to fundamental physics in the face of the idea of multiple realization (Sec. 2.5); the implications of this idea with respect to psychology (Sec. 2.6). In Section 3 we address the metaphysical framework in which Albert and Loewer formulate The Mentaculus: David Lewis' metaphysics and the best system approach to laws and Loewer's improvement of it in his (2020b) Package Deal Approach (PDA). In Section 4 we consider the non-reductive nature of the special sciences in the Mentaculus.

2. Flat Physicalism

In this section we present Flat Physicalism. While Flat Physicalism *resembles* The Mentaculus in that it is an "outrageously ambitious" theory that is "arguably a complete scientific theory of the universe”, and that its way to achieve this aim is by a generalization of statistical mechanics, it *differs* from The Mentaculus in important points concerning its conceptual basis. The difference fundamentally concerns the metaphysical basis: The Mentaculus is seen by its authors as a “best system” that is supposed to provide an informative and simple description of the Humean base, which is the fundamental reality, whereas in Flat Physicalism the fundamental reality is the physical one, and there is nothing else and in particular nothing more fundamental than physics.

One important consequence of this difference is that in Flat Physicalism everything is supposed to be accounted for by NM and CF only (see Sec. 2.1 and 2.2), whereas in The Mentaculus additional fundamental elements are assumed, namely PH and SP. In this sense Flat Physicalism, if successful, is simpler (see Sec. 2.3 and 2.4). In addition, Flat Physicalism derives from NM and CF the laws and properties of the special sciences including psychology (Sec. 2.5 and 2.6), as well as a notion of chance in a deterministic world (see Sec. 2.3).

Due to this difference, in Flat Physicalism - unlike The Mentaculus - the PH, SP, the special sciences and the notion of chance are all derived from CF+NM. This is the main reason why it is simpler, and hence “better”, than The Mentaculus. Perhaps The Mentaculus can be changed so as to incorporate some ideas from Flat Physicalism, to become simpler, more reductionist, and more physicalist, but then it becomes so close to reductive physicalism that the difference may cease to be significant. We will discuss this consequence later.

As we said above, in this paper we present statistical mechanics as the project of accounting for the thermodynamic (and other) regularities by *classical* mechanics, as is usual (and as was done with respect to The Mentaculus in Sec. 1 above). The justification for doing so is the conjecture that although classical mechanics is strictly speaking false, it preserves some of the salient explanatory and predictive aspects of the true fundamental physics, under the appropriate conditions. (See Wallace 2001 Sec. 1, and Ladyman and Ross 2007. See Shenker 2020 on quantum statistical mechanics.)

2.1 Microstates: fundamental physics

Statistical mechanics, as the project of accounting for thermodynamics by classical mechanics, consists of two (related) stages. First, express the thermodynamic quantities (such as volume and temperature) in terms of mechanical quantities (like mass, position, and velocity). Second, prove that due to the laws of mechanics (e.g., F=ma) and some contingent fact (i.e., together with some auxiliary hypotheses[10]) these mechanical quantities evolve in a way that mirrors the thermodynamic regularities (such as the ideal gas law or the Second Law). In this paper we focus

[10] These auxiliary hypotheses are described in (Shenker 2017b, 2017c).

on the first stage (for the second stage see Hemmo and Shenker 2012, 2016, Shenker 2017b, 2017c), and therefore we begin with the ontology of fundamental physics.

According to classical mechanics the universe consists of particles each having properties or parameters such as mass or charge, that are subject to certain constraints and limitations such as total volume available to the particles or the total energy available to all of them, and each of them has, at each point of time, precise and well defined position and velocity.[11] The positions and velocities of all the particles at a time is called the universe's "*microstate*" at that time.[12] The microstate, together with the parameters and constraints, is everything that there is at every moment, according to mechanics. For brevity, henceforth by the term "microstate" we will refer also to the parameters and constraints.

The following terminological remark is of utmost importance for understanding statistical mechanics. There are various notions of *'microscopic'* in the literature: the term sometimes means small, and sometimes part of a whole. But in statistical mechanics it is customary to use the term 'microstate' to denote the complete state of the system of interest, or of the world, according to the fundamental theory, which is here classical mechanics. For instance, in classical mechanics the precise positions and velocities of the particles of the entire universe is a microstate, despite the fact that it is neither small nor part of anything.

Albert (2000 Ch. 1) points out that the microstates are not independent of each other: since instantaneous velocity is part of the microstate, the microstate in a given moment imposes constraints on the positions in the microstates in its temporal vicinity. The requirement of independence may be important for Lewis's original characterization of the Humean base (see Sec. 3), but (we think) not for Loewer's (2020) recent PDA version of it (that we address in Sec. 3). In any case, according to Flat Physicalism the fundamental reality is as described by physics.

Given the microstate at some moment, together with the parameters and constraints, the equations of motion of classical mechanics determine the microstates at all other moments, that is, an entire history or an entire *trajectory* of the universe.[13] While we can perhaps conceive of counterfactual microstates, and hence on counterfactual histories, *the actual micro-history is everything that there is*, according to classical mechanics.

[11] Zeno's arrow paradox needs to be solved here; see (Arntzenius 2000).

[12] Microstates can be thought of as events, not states. We don't expand on this point.

[13] In quantum mechanics the micro-history of the universe is determined by the equations of motion of the quantum state. Some interpretations postulate also "collapse" of the quantum state, either deterministically or non-deterministically.

2.2 Aspects: macrovariables and macrostates

Normally, we are not interested in the full details of the microstate of a system or its micro-history: we are interested in certain sub-systems of the universe, and in certain properties of those sub-systems. In particular, we are interested in properties of systems that exhibit regularities that we can follow. For example, in thermodynamic systems we are interested in the volume of a gas, or the degree of uniformity of its temperature. We just said that the microstate is everything that there is; and this entails that properties like volume or temperature cannot be facts over and above the microstate. Indeed, those properties are *aspects* of the microstates, sometimes called *macrovariables*.[14] For example, volume is an aspect since it is a function (certain coarse-grained distribution) of the positions of the system's particles, and does not pertain to all the details of these positions nor to the velocities of the particles. (The description of an aspect (of a macrovariable) is a partial description of the microstate; but we stress that we focus on what there is, about *ontology*, and not about how it can be known or described.)

It has been discovered - and this is a highly non-trivial discovery by the creators of statistical mechanics - that certain aspects stand in lawful relations to certain other aspects, either at a time (synchronically) or over time (diachronically), and these aspects and their lawful relations have been *identified* with thermodynamic magnitudes and the laws governing them. Here is what we mean by "identified": Since the microstates and micro history are everything that there is in the universe, the thermodynamic magnitudes and regularities are *nothing over and above* aspects of the mechanical microstates and micro histories. That is to say: The thermodynamic magnitudes do not only "supervene" on the mechanical ones; they are *them*.[15]

A famous example of an aspect is the Maxwell-Boltzmann energy distribution. To know whether this aspect obtains in the particular sample of diluted gas in front of us, we carry out indirect measurements of *other* aspects, e.g., to see whether the gas is uniformly spread in the container

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[14] The notion of aspect is in some sense perspectival. But, since this perspective is derived from the complete microstate by partial description there is no danger of inconsistency between the perspectives, nor of not knowing "perspective of what", especially where theoretical entities are concerned (see Arabatzis 2016).

[15] Gibbs (1902) talked about "analogies" and only later - and not always - his quantities came to be understood in terms of identity statements. In Boltzmann's thought (see Uffink 2017) this is less clear, and Boltzmann and Maxwell came to identify certain macrovariables with certain thermodynamic quantities due to the similarity in the regularities that they exhibit. See overviews in Frigg 2008, Uffink 2007, Sklar 1993. The Gibbsian picture of statistical mechanics differs from the Boltzmannian one in important details (see Callender 1999; Uffink 2007; 2017; Frigg 2008, Wallace 2015, Goldstein, Lebowitz, Tumulka, and Zanghì 2020), and therefore the predictions of these two approaches agree only approximately (see Werndl and Frigg 2017, Jaynes 1965). However, in both traditions thermodynamic magnitudes are associated with macrovariables or functions of macrovariables. See more on the connection between these pictures in (Hemmo and Shenker 2012, Ch. 11).

and its temperature is distributed uniformly in it, or whether when we increase the pressure on it, its temperature increases in direct proportion, in accordance with the ideal gas law. And so, the main idea of statistical mechanics, which makes it so important and useful, is that in order to provide a successful and informative account of thermodynamic phenomena one needs only partial information about the microstate of a system, that is, one needs only to specify its *aspect*.

The notion of aspect has two characteristics, and their interplay is the core of statistical mechanics and the basis of expanding it to a general theory of reductive physicalism.

(i) *The aspect of the actual microstate is what we observe*. When we measure the volume of a gas, for example, what we interact with is the *actual particular* distribution of the positions (or the actual sequences of particular positions) of the *actual particular* sample of gas in front of us. There isn't anything else in the world for us to observe. (We don't measure sets of counterfactual states; see (ii) below.)

(ii) *The aspect of the actual microstate describes an equivalence set of microstates, called "a macrostate"*. When we measure the volume of a gas, for example, and find that it is (say) V, this partial information is all that *we* have about this sample of gas, and as far as *we* are concerned it could have been in any number of microstates, provided that they share this aspect, this coarse-grained partial description of the molecules' positions. Thus, this ignorance concerning the other details of the gas' microstate (everything except V) gives rise to an equivalence set of microstates, namely, those that share the aspect V and differ in all other aspects. The set is an *epistemological* notion. *Ontologically*, one microstate in the set is actual at the time of measurement, and all the others are counterfactual; some will become actual in other times, most will not.

The set of counterfactual microstates that share an aspect is sometimes called *macrostate*, and this is how we shall use this term here. The *aspect* (*macrovariable*) of an actual individual microstate (or micro history) is "out there in the world", as the entire actual microstate is; but the *macrostate* - as set of *counterfactual* microstates - is not "out there in the world"; it is only a theoretical construct. *Microstates and aspects (macrovariables) are in the world; macrostates are not.*

Of course, macrostates are extremely important theoretical constructs, and serve various epistemic purposes: they enable us to talk about *entropy* (i.e., the degree to which the energy of a system can be exploited by manipulating the system via external constraints) and *probability* (i.e. predicting the future values of the aspects (macrovariables) of the system's microstates). We discuss probability in Section 2.3. We discuss the notion of entropy only very briefly in Section 2.4 (see Hemmo and Shenker 2012 Ch. 7). (In the literature the terms macrostates and macrovariables are sometimes used interchangeably,[16] or other terms are used. See various examples in Ehrenfest and

[16] In (Hemmo and Shenker 2016) the terminology is a bit different: *macrovariable* refers to any aspect of a microstate, and *macrostate* refers to those that appear in our experience.

Ehrenfest 1912; Sklar 1993; Lebowitz 1993; Goldstein and Lebowitz 2004; Frigg 2008; Uffink 2007.)

2.3 Probability in Flat Physicalism vs. The Mentaculus

Since Flat Physicalism is committed to the idea that the microstate and micro-trajectory of the universe are everything that there is in the universe, if there are probabilistic facts in the universe then those have to be part of this fundamental ontology, namely of CF+NM, for there is nothing else that they can be. In this section we show how probabilities come about in a deterministic world in Flat Physicalism. This reductive approach is by contrast to the non-reductive Mentaculus proposed by Albert and Loewer.

Albert and Loewer's Statistical Postulate (SP) posits a probability distribution over the past low entropy macrostate of the universe: the postulate is that this probability distribution is uniform relative to the Lebesgue measure. According to Albert, as we saw above,

> "the right probability distribution to use for making inferences about the past and the future is the one that's uniform, on the standard (i.e., Lebesgue) measure, over those regions of phase space which are compatible with whatever other information – either in the form of laws or in the form of contingent empirical facts – we happen to have." (Albert 2000, p. 96)

Since SP forms part of The Mentaculus, it is taken to be a fact over and above CF+NM. Since SP is defined over *counterfactual* microstates (or micro-trajectories), it denotes a fact in addition to the *actual* trajectory of the universe, which is fixed by CF+NM. The justification for adding SP to The Mentaculus is that together with it (but not without it) The Mentaculus becomes the "best system" (Loewer 2001, Albert 2014, pp. 23-24). Albert explains this move by an "audience with God" who upon our request for the "best system" of our world adds SP over and above NM:

> "I have something more to tell you as well… Something about the initial condition of the world… it was one of those which is typical with respect to a certain particular probability distribution - the Boltzmann–Gibbs distribution, for example. The best I can do by way of a simple and informative description of that initial condition is to tell you that it was precisely the sort of condition that you would expect, that… you would have been rational to bet on, if the initial condition of the world had in fact been selected by means of a genuinely dynamically chancy procedure where the probability of this or that particular condition's being selected is precisely the one given in the probability distribution of Boltzmann and Gibbs." (Albert 2014, pp. 23-24)

God in this parable just informs us, top-down, that *if* we assume this particular probability measure then the *actual* matters of fact, the actual observed regularities, will turn out *likely*, so that it would be rational to expect them (perhaps in the framework of Lewis's concept of probability, see Lewis 1980b; Hoefer 2019). Albert takes this to justify endorsing SP as part of The Mentaculus. This kind of justification for choosing a probability measure, and for explaining the actual matters of fact, is assumed by supporters of the so-called "typicality" approach (although for some of them the measure is not one of probability; see Dürr 2001). The typicality approach is the subject of an ongoing debate (see Dürr 2001, Dürr, Goldstein and Zanghi 1992, Maudlin 2007a, Callender 2007, Goldstein 2012). Some think that the probability measure can be derived from theorems of mechanics or by dynamical considerations: were this the case it would provide a way to derive the SP from CF+NM, but we have shown that those considerations are irrelevant for determining the measure in question. This means that the typicality approach is non-reductive and introduces the measure as an additional fact, not derivable from the mechanical principles and the contingent facts. (On why the typicality approach is unacceptable for being circular see Hemmo and Shenker 2015b.)

In the "best system" approach, within which Loewer and Albert work, adding a postulate such as SP to the laws of nature is justified if it makes the system of laws the "best" balance between informativeness and simplicity with respect to the Humean base, even if it comes about via divine revelation. (See Sec. 3 for more on the relation between The Mentaculus and the Humean base in a Lewis-style approach.)

Can the endorsement of the SP be justified on the basis of CF+NM, without a decree from God? Arguably, such a possibility would lead to a simpler and "better" system. We now turn to showing how the probability in classical statistical mechanics can be derived from NM and CF, so that there is no need for an independent postulate like SP. By this we will show that the probability is a feature of the actual (deterministic) trajectory of the universe, and in this sense, it is an objective feature of the world despite the underlying determinism.

Consider Figure 1 which illustrates the state space of some system. The microstates in this state space are partitioned into sets (M_0, M_1, M_2) that are macrostates: in each set all the microstates share some aspect (macrovariable) of interest. Other details in the figure are explained later.

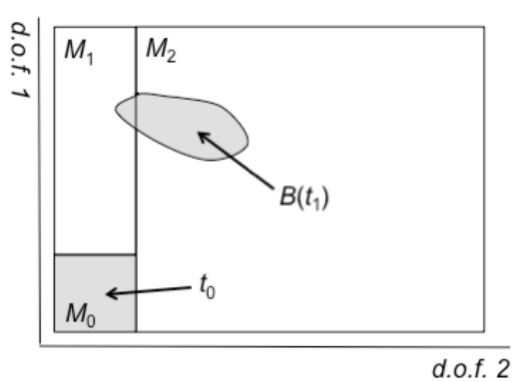

Figure 1

Suppose we prepare a system G with a thermodynamic property associated with the macrovariable M_0. This means that the initial *actual* microstate $x(t_0)$ of G - whose macrovariable M_0 we *actually* observe and prepare - belongs to the macrostate-set M_0 in Figure 1, in which all the microstates share the same macrovariable M_0; all of them except $x(t_0)$ are counterfactual and do not obtain in reality at t_0. We now follow the evolution of each of the continuous infinity of microstates in M_0, tracking its trajectory from its starting point within M_0 at t_0 until time t_1, and call the set of all the end points $B(t_1)$.[17] The Lebesgue measure of $B(t_1)$ is the same as that of M_0, satisfying Liouville's theorem. Needless to say, saying that "we calculate" $B(t_1)$ in this way is a *huge idealization*: we may say that Laplace's *Demon carries out this calculation, but in practice there are shortcuts* for special interesting cases (see discussion of these shortcuts in Hemmo and Shenker 2012, Sec. 6.5 and 6.6). Despite these shortcuts, discussing the idealization is important in order to understand how probability emerges in the theory and thus helps to see what exactly is involved in those shortcuts. We shall see below additional shortcuts, and those need to be understood as such; without understanding the idealization it is hard to see that our actual practices are shortcuts and those may be given an exaggerated ontological status. This is why we emphasize them here and below.

In general region $B(t_1)$ partly overlaps more than one macrostate, and in our example it partly overlaps with M_1 and partly M_2. In this sense, the following if-statement is an objective fact about the system G: *if* it is prepared in a microstate with the mechanical macrovariable M_0, *then* its final microstate will be one with either macrovariable M_1 or M_2. And the transition (or conditional) probability that a system prepared in M_0 at t_0 will end up in M_1 at t_1 is determined by the relative measure of the overlap of $B(t_1)$ with M_1; and similarly, for M_2: That is, the transition probability (or conditional probability) is given by the following probability rule:

Probability Rule: $P(M_1, t_1 \mid M_0, t_0) = m(B(t_1) \,\&\, M_1)$. (1)

Here "$P(M_1, t_1 \mid M_0, t_0)$" is the probability that the microstate of the system at t_1 will turn out to be in M_1, conditional on its being in M_0 at t_0; "$B(t_1) \,\&\, M_1$" denotes the *intersection* of the phase space regions $B(t_1)$ and M_1; and $m(x)$ is the normalized measure of the region x in the phase space, given some appropriate measure m; we discuss below how to determine the measure.[18] Obviously, the empirical adequacy of this rule should be tested against the relative frequencies we observe.

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[17] The region $B(t_1)$ is a sort of Poincare section: Normally Poincare sections are used to describe semi-periodic systems, but the principle is the same.

[18] If the states are confined to, for example, an energy hypersurface, on which all regions have measure zero relative to the entire phase space, then the above rule is modified such that the measures of sets are relative to this hypersurface.

How is m(x) fixed? According to Flat Physicalism, since the micro history is *everything that there is*, the task is to derive m(x) from it. Briefly and ideally, this is the way to do it.

Step 1: given some particular M0 of interest, calculate the continuous sequence of regions like B(t1) in Figure 1, along the entire infinite continuous trajectories; this is, of course, another huge idealization, for which there are useful shortcuts. Step 1 is based on CF+NM (but not on SP or PH). We assume here that CF is true (see Sec. 1) and we don't seek to derive the truth of CF (with high probability) from anything, since we don't think that this is possible (see below).

Step 2: follow the *actual* micro-trajectory as it passes through these B(t) regions, and count (by calculation) the *actual* relative frequencies of the different Mi along the infinite continuous micro-trajectory. Again, our resources here are only CF+NM. Of course, this is another huge idealization. The *shortcut* that we use *in practice* is to measure the M_i values in actual experiments on similar systems in the actual short history through which we live, and to generalize the observed relative frequencies by induction, hoping that it works; the usual problem of induction applies.

Step 3: choose a measure over the B(t), and thus in practice over the entire accessible region, that will be compatible with these relative frequencies. Step 3 is a derivation from CF+NM only. In general, there will be more than one such measure; any of them will do; choose any of them, either arbitrarily or the most convenient one. Since the measure is chosen such that it fits the observed relative frequencies, it cannot be taken to account for the high probability of those same relative frequencies; this is why, as we said, one cannot come up without vicious circularity with an empirical theory which gives high probability for the truth of CF. This point stands at the heart of the question concerning the origin and nature of the probability measure (or the measure of typicality) in statistical mechanics.

Notice that in this approach the obtained probability measure can be time-dependent. Indeed, even SP is a time dependent probability distribution. Notice that distributing probability uniformly in a time-independent way yields empirically inadequate results, which is a known problem for Boltzmann's approach; see (Hemmo and Shenker 2015c).

Step 4: apply the results, possibly by tracing backwards the history of the universe until the putative "big bang" moment, and apply the chosen measure. The result will be SP only if it is true. In this way SP is not a postulate at all, but a result derived from CF+NM.

By adding SP to The Mentaculus Albert and Loewer *assume* - without justification, neither theoretical nor empirical - that Steps 1-3 will yield the particular probability distribution that it mentions. In Flat Physicalism, by contrast, there is no guarantee that the probability distribution described in SP is true. It is endorsed subject to the assumption involved in the shortcuts and inductive generalization described above. Flat Physicalism also brings out the fact that the measure is not a fact out there in the world, but a mere convenient tool for calculations. In The Mentaculus, it is given the status of an *additional* law of nature, *irreducible* to the rest (Loewer 2001, 2008); in Flat Physicalism, it is derived from CF+NM. Since classical mechanics describes the world in terms of differential equations, there is no way to avoid introducing CF in addition to NM. (See more details, including shortcuts to overcome the difficulties of the idealizations involved in the Flat Physicalist account of probability, in Hemmo and Shenker 2012, 2019 and Shenker 2017b, 2017c.)

Since our description of how the chances come about is reductive and is in fact a generalization of our experience of relative frequencies of certain macrovariables along the actual trajectory of the universe, the probability law (1) is itself not fundamental, but a derived law.

In the Flat Physicalist concept of probability described above the probability measure is fixed by the harmony between two elements: (I) The dynamics, (II) The partition of the state space into macrostates. Let us comment on these two.

(I) The dynamics. On the Flat Physicalist concept of probability, a different dynamics, or different initial conditions, will yield different probabilities. The probability rule is general, in this respect, and should it be discovered that the dynamics of the universe is different from what we thought, the probability rule will be able to accommodate this fact.

(II) The partition. On the Flat Physicalist concept of probability, a different partition of the state space into macrostates will yield different probabilities. It is useful to see the significance of this point by comparing Flat Physicalism with The Mentaculus. Albert and Loewer's SP pertains to a certain macrostate, the "big bang" one. But, the *complete ontology* of the big bang is given by a particular (unknown) actual microstate, which is supposed to be a member of the "big bang" macrostate set. The big bang *actual micro*state - as any microstate - has (infinitely) many aspects, (infinitely) many macrovariables, and each of them gives rise to a different partition of the state space, and thus to a different big bang *macro*state. Which of them is the one that features in PH and SP? In Albert and Loewer's Mentaculus approach a certain partition of the state space into macrostates has a preferred status, and it is not clear where exactly this preferred status comes from. There seems to be something *a-priori*, and even something *metaphysically dualistic*, about this preferred partition. Flat Physicalism, by contrast, accepts that according to NM all the partitions to macrostates are on a par, and the probability rule of Flat Physicalism gives rise to a host of probability statements, each pertaining to a different partition of the state space. The only way to explain why it is that *we*, human beings, experience certain macrovariables rather than others (e.g., the thermodynamic macrovariables), pertains to contingent facts about our physiology, the way that we interact with our environment and facts about the physics of the mind (see Hemmo and Shenker 2016, on "*Ludwig's problem*"). Those are not additional facts: they are all part of CF+NM, because there is nothing else in the universe, according to Flat Physicalism.

(This is why reductive physicalism about the mind is an essential element of statistical mechanics; see Shenker 2017a, Hemmo and Shenker 2020.)

What is the fate of the Second Law in Flat Physicalism? Suppose that the probability rule (1) yields high transition probabilities for entropy increase as required by the Second Law. This would mean that along the *actual* trajectory of the universe the relative frequencies of macrostates conform to the Second Law probabilities. But one cannot derive from this result anything about the behavior of other counterfactual trajectories. In general, the probability rule is compatible with Second Law behavior along one trajectory as well as with Maxwellian Demons along other trajectories (see Hemmo and Shenker 2010, 2012, 2016).

As we said above concerning other elements of The Mentaculus, if one accepts the Lewis-style "best system" approach, then the only criterion for whether or not one needs to introduce an additional postulate to one's laws of nature, e.g. adding the SP to CF+NM, and the way that one should understand the notion of probability in a deterministic world, is if it contributes to the system being "better" (see Hoefer 2019 on Humean chance). We think that since Flat Physicalism derives the notion of probability from CF+NM, then it is "better" (the other option is that there is an external source of support outside or in addition to the micro-trajectory; see Sec.1; and this will make both the theory and the Humean base much more complex).

2.4 The Past Hypothesis in Flat Physicalism

In Section 2.3 we saw how probability comes about in Flat Physicalism as a consequence of a certain harmony between the dynamics and the partition of the state space into macrostates, which is a consequence of CF+NM. Assume a certain combination of NM and CF, and focus on a certain partition, e.g., a partition into thermodynamic macrostates. And suppose that we can prove that (either generally or for certain conditions) a mechanical counterpart of the Second Law of thermodynamics will continue to obtain. Then, as is well known, it is a theorem that a time reversed "Second Law" obtains as well, and to avoid this consequence Feynman (1965) and Albert (2000) postulate the PH. On this view the PH is a postulate, it is not derived from CF+NM. However, Flat Physicalism seeks to derive everything from CF+NM. How is the PH derived?

Here we employ three steps.

First, the temporal directionality. It is a point of logic that asymmetric consequences are not derivable from symmetric assumptions. Hence to break the symmetry between past and future a symmetry breaking assumption needs to be introduced. There is no way out of this. The only question is whether there is a trick that will enable it without adding anything to CF+NM. We think there is; our solution is that what is felt in our mind to be a temporal asymmetry is reduced to a non-temporal asymmetry of the structure of our brain, which gives rise to the psychological arrow of time, and which is part of CF. By contrast, Albert (2000, 2014) and Loewer (2001, 2012, 2020a) argue that the symmetry-breaking fact is the PH; see our (2019a).

The second step, once we have a temporal asymmetry, is to retrodict the past. Predictions are carried out using probability statements as illustrated in Figure 1 in Section 2.3, and they contain ignorance concerning the macrostates (or more precisely macrovariables) that will actually obtain when the time comes. Retrodictions, by contrast, involve some ignorance as well as some knowledge concerning the macrostates (or more precisely macrovariables) that actually obtained in certain moments in the past. (Here we need a concept of records, that we don't discuss here; our concept is different from Albert's 2000.) Conceptually, retrodictions are measurements: we retrodict the past possible macrovariable in a manner similar to the prediction of Figure 1, and then "measure", by recollecting, which of the macrovariables actually obtained (for details see Hemmo and Shenker 2012, Ch. 10). Measurements, in this framework, end by the measurer having a certain brain state in which she believes that a certain state of affairs obtained, and therefore this notion is perfectly reducible to CF+NM.

Notice that on this view Flat Physicalism explains retrodictions in a way that does not guarantee that the PH obtains! Postulating the PH may solve what Albert has called the "skeptical catastrophe", according to which The Mentaculus *minus* the PH implies that our memories of past events, including the past events that we take to support NM and CF in the first place, are not true (or unreliable). But - as desirable as this result may be - it is not guaranteed (not even probabilistically) by CF+NM. Flat Physicalism accommodates the fact that CF+NM are compatible with violations of the Second Law as well as with the possibility that the PH is false. The "skeptical catastrophe" must be dealt with by NM and CF alone; and the way this done in Flat Physicalism is simply by taking CF to be true as a starting point, or a working hypothesis, although it is open to the possibility that its contents is false (see Sec. 1).

Flat Physicalism also accommodates the fact that there is a host of different partitions of the state space into macrostates, all of which are on a par, while the thermodynamic partition is just one of them. The PH in The Mentaculus concerns the "low-entropy highly condensed big-bang sort of macrocondition it is that the normal inferential procedures of cosmology will eventually present to us." (Albert 2000, p. 96). That is, it elevates the thermodynamic partition to the status of a law, even though given NM all partitions of the state space have equal status. As we said, the only way to explain the preference of the thermodynamic partition pertains to contingent facts about our physiology, the way that we interact with our environment and facts about the physics of the mind (see Hemmo and Shenker 2016, on "*Ludwig's problem*"). Although in Flat Physicalism these facts are all part of CF+NM, they do not give the PH a preferred status, let alone the status of a law of nature.

Finally, the PH is given in terms of "entropy". What is entropy, in Flat Physicalism? Again, we will not go here into the full details, and just make the following remarks concerning what entropy is and how it is to be expressed in terms of CF+NM.

(1) While the meaning or reference of thermodynamic entropy is not always clear (see e.g., Uffink 2001) one of the ways it is often understood is as quantifying the degree to which energy can be exploited. In our view this idea should be translated, or rather transformed, into the notion of controlling the system's microstate. Intuitively, the smaller the macrostate-set corresponding to the macrovariables we can manipulate is, the closer we are to zooming in on the actual microstate and controlling it. This is the intuition behind associating the measure of macrostates with their entropy (in a Boltzmannian framework; for the connection to the Gibbsian approach see our 2012 Ch. 11).

(2) But how should the measure be chosen? We saw in Section 2.3 that this is a subtle and problematic issue that invites fallacies or petitio principii. To avoid these dangers, we note the following.

(3) In thermodynamics, entropy quantifies the degree of exploitability of energy *only if* the Second Law is true (see Fermi 1936, and our 2012 Ch. 2).

(4) Entropy and probability are two distinct concepts: the measure of entropy should quantify exploitability, and the measure of probability should provide correct predictions of future macrostates. Therefore, there is no reason at all - elegance notwithstanding - that the measure in the two cases should be the same. We propose (in our 2012, Ch. 7) to choose the measure of entropy such that the phenomena of the Second Law of thermodynamics will be recovered; we do that in view of comment (3) above.

(5) Finally, notice that entropy is a number without units, a hint that it is not out there in the world: there isn't, and there cannot be, an entropy measuring device. Entropy is the measure of a set of counterfactual states of affairs. The only way to measure entropy is to measure some macrovariable, e.g., the degree of uniformity of temperature in a given sample of gas, and then to define the macrostate set of counterfactual microstates that share this macrovariable, and then introduce the measure as in remark (4) above, and *calculate* the entropy. Entropy is not a fact "out there in the world", but a very useful theoretical construct. The PH inherits this nature of entropy.

2.5 Special sciences: a reductive account

Sometimes it seems that the special sciences, such as biology or geology, describe facts about the world that are over and above those described by physics. The commitment of Flat Physicalism is that this is not the case. If the microstates and micro histories are everything that there is, then the magnitudes and regularities described by the special sciences must be features of the microstates and micro histories; for there is nothing else they can be. *Reductive type-identity physicalism* is the view that the magnitudes and regularities of the special sciences are nothing but aspects (macrovariables) and the regularities that they may exhibit along the micro trajectory, while the complete microstate evolves according to the equation of motion. In order to come up with the best system of the laws of a certain special science (e.g., biology, economics), one needs to follow the same kind of derivation we presented above with respect to the laws and facts of thermodynamics (which is one example of a special science, after all) from CF+NM. This means that according to Flat Physicalism the best system of laws for the entire world which includes the laws of *all* the special sciences is NM.

Our example of a special sciences is thermodynamics. In our view the science of thermodynamics, despite the fact that it is studied by physicists, has the status of a "special science": the very project called "statistical mechanics" is the attempt to account for the thermodynamic magnitudes and regularities in term of those of fundamental physics (be it Flat Physicalism or The Mentaculus), and this is precisely the way that the (other) special sciences are treated in Flat Physicalism. In Flat Physicalism, then, the microstate and the micro history are *everything that there is* in the universe, and therefore the magnitudes of thermodynamics (such as volume or temperature) *are* (*identical to*) aspects of the microstates, and the regularities exhibited by the thermodynamic magnitudes *are* (*identical to*) the ways these aspects evolve along the micro-history of the universe and its subsystems. According to Flat Physicalism this is the way - *the only way* - to account for the other special sciences as well, for example biology or geology, because the microstate and the micro history are *everything that there is*. (We return later to the subtle question of the status of thermodynamics in The Mentaculus.)

The picture that Flat Physicalism proposes is flat: there are no levels of reality. So-called "high-level" kinds (such as temperature) are understood here as aspects, or macrovariables, given by partial descriptions of the microstructure of a single level of entities and their interactions, as described by the fundamental theories of physics. This is the essence of Flat Physicalism.

One challenge for Flat Physicalism in this context is the following. It is a prevalent view in contemporary philosophy of science that certain special sciences kinds are *multiply realized* (or at least *multiply realizable*) by physical kinds. Allowing for multiple-realizability is more or less a standard view in contemporary thinking, especially in functionalism (since Putnam 1975; Fodor 1974; Davidson 1970; and of course, Lewis 1966, 1980a). When taken together with supervenience of the special sciences kinds and properties on physical ones, this view is called "*non-reductive physicalism*". Whether or not experience supports this claim is an open question (see e.g., Polger and Shapiro 2016); We shall not argue for nor against the factual existence of multiple realizability. Our task, rather, is to show how Flat Physicalism can account for the appearance of multiple realizability, should it turn out to be an empirically verified fact. Here is an interesting example. The macrovariables associated with the thermodynamic magnitude called "temperature" in an ideal gas (in which there are no interactions between the molecules) is different from the one in a van der Waals gas (in which there are the simplest interactions between the molecules), and the two cases agree quantitatively only in certain limiting conditions. "Spin temperature" is yet another aspect of the (quantum!) microstate, and there is supposed to be quantitative agreement (in relevant scale) between it and the other macrovariables associated with the notion of "temperature". Frigg and Hoefer (2015) see this as a case of multiple realization. They write:

> "[M]any non-fundamental properties are multiply realisable, meaning that the same non-fundamental property can be realised by a number of distinct fundamental kinds. This is true not only in psychology (the classical example being pain); we find multiply realised properties even in close-to-fundamental physics: temperature in gases and temperature in spin systems have *completely different* micro-realisers." (Frigg and Hoefer 2015; our italics.)

For Frigg and Hoefer there are high-level facts that are not in the microstate or micro history: for example, the fact that "temperature in gases" and "temperature in spin systems" are both cases of "temperature" cannot be explained by the micro-structure of the world, because at the micro level they are "completely different" - they do not share any aspect (any macrovariable) that could explain this fact. By "*genuine multiple realization*" we mean a case in which the fact that the different "low-level" cases appear to be multiple realizations of the same "high-level" fact cannot be explained by a hidden or unnoticed "low-level" fact that they share. According to Frigg and Hoefer (if we understand them correctly) the case of temperature is one of genuine multiple realization.

Flat Physicalism, insisting that there is nothing over and above the microstate and micro history, has to offer a different account of the case of temperature. Two options are open for the Flat Physicalist in this case.

Option 1 is that, first impression notwithstanding and even contemporary scientific knowledge notwithstanding, there is an *aspect* of the microstate that is shared between "temperature in gases" and "temperature in spin systems", and this shared aspect is (identical with) "temperature".

Option 2 is when this is not the case, that is, when the microstates of the "temperature in gases" and "temperature in spin systems" are "completely different" or *heterogeneous*. In this case Flat Physicalism makes the following observation. When *we* say that "temperature in gases" and "temperature in spin systems" are both cases of "temperature" what happens is precisely this, namely, that upon interacting with either "temperature in gases" or "temperature in spin systems", *we* enter a brain state that says, "this is a case of temperature". The fact that in both heterogeneous cases (of "temperature in gases" and "temperature in spin systems") our brain enters the same state is not a result of us measuring the quantity of "temperature" in those objects, since - by assumption - they do not share anything the measuring of which will yield the same outcome. We just happen to enter the brain state saying, "this is temperature" for no reason at all - that is, for no reason about the "temperature in gases" and "temperature in spin systems". It is a case of pure coincidence. We give the same name, if you will, to two distinct things, in a way similar to giving the same name to two different people: giving them the same name does not indicate that they share any property.

However, even in this case there is a shared physical fact between the cases of "temperature in gases" and "temperature in spin systems", and it is *our* brain state that says "temperature". In other words, if we *extend* the microstate, to include - in addition to the gas or the spins system - also the observer, then the microstates share an aspect, namely, the state of the brain of the observer. Consider an alien observing a gas and a spin system: if the microstate and micro history are all that there is, then the alien will not see them as sharing anything, because they *don't* share anything. This is why Option 2 is a case of *apparent but not genuine* multiple realization: Flat Physicalism opens our eyes to the fact that the *seeming* of multiple realization (if indeed it so seems) is a result of ignoring our role as physical observers that partake in the extended microstate.

Of course, this latter option is highly counter-intuitive, for it means that the observer does not *discover* which things belong to the special science kind, but rather *creates* that kind. The things out there do not share anything to be discovered (since the physics is all that there is, and the things out there do not share anything physical) and the only thing that makes them a kind is the shared brain state of the observer, which just happens to be the same, by pure coincidence and for no reason at all - again, in a similar way that different people happen to have the same name. But we must allow for this option, which may explain some contingencies of human history.

Option 3? Supporters of *genuine* multiple realization claim that neither Option 1 nor Option 2 obtain, and nevertheless aliens will sense that "temperature in gases" and "temperature in spin systems" are of the same kind, "temperature". How can this case be explained? Flat Physicalism will then *have* to admit that the physical facts are not everything that there is: there are non-physical facts as well, and those are the facts that the alien can sense, and in virtue of which it will discover empirically that "temperature in gases" and "temperature in spin systems" are of the same kind, "temperature". This is *token dualism*. *Flat Physicalism will, in this case, fail and turn out to be false*. And so, the claim of our Flat Physicalism approach is that the name "non-reductive physicalism" is a misnomer: an approach that allows for genuine multiple realization is not physicalism at all, but is an approach of *token dualism*.[19]

[19] By the way, we propose here that Putnam's famous Twin Earth thought experiment, in which two substances, XYZ and H_2O, bring about in the observer the same experience, should be analyzed along these lines, and similarly Kripke's (1980) "theoretical identifications" such as "water is H_2O" (see Hoefer and Marti 2019). Importantly, water is not a mere "Lego"-like composition of particles (see Chang 2012,

Another way to see this is the following. If, as Flat Physicalism conjectures, the facts of fundamental physics are everything that there is, then by looking at the token microstate or micro history one is (ideally) able to know everything. In particular, one is (in principle) able to know, given the microstate, to which high-level kinds a system belongs. By contrast, if multiple realizability obtains, this is not possible, since the very fact that certain heterogeneous physical kinds (but not others) all under the same special-science kind, is not derivable from the fundamental physical facts. This partition needs to be given top-down, that is, from some source that is not part of the physics of the system or of the world. Importantly, *even if supervenience obtains*, unless one receives information "from above" concerning *which* physical kinds are subsumed under *which* high-level kind, this information is not, and *cannot* be, available by looking at the system of interest. This is clear *token dualism*.

For these reasons, Flat Physicalism is the conjecture that the hypothesis of multiple realizability is false. The special sciences kinds and regularities are those of fundamental physics: this is a reductive type-identity physicalist view.

2.6 Mental kinds

We said that Flat Physicalism can account for all the cases of *apparent, non-genuine* multiple realization in the special sciences such as biology or geology, by appealing to the observer and extending the microstate to include it (Option 2 above). But this line of explanation does not apply for the science of psychology. The reason is this. (And the reason has *nothing* to do with the so-called "hard problem of consciousness" and notions like subjectivity, qualia, etc. The problem is totally *different*, and is the following.)

It is often said in contemporary literature that psychological kinds (e.g., pain) are realized by different creatures, e.g.: by different human brains, and *ipso facto* by non-human brains, a famous example being Putnam's (1975) octopus pain. Let us assume here, for the sake of the argument and without arguing for or against it, that indeed octopuses and human beings share something about their mentality (not only about their behavior!), and that the shared thing is that they are both "in pain". A point that we find important is this: admittedly there are different kinds of pain; we know this to be the case in humans, and *ipso facto* it is the case with respect to non-human animals;

2015): the interactions responsible for the existence of each molecule and for their combination to form water are described by the theories of fundamental physics, and form part and parcel of the aspects of the fundamental physical state of affairs that we call "water"; there is no residue that calls for explanation in terms of other metaphysical relations like grounding, determination, realization, etc.

still, the assumption here is that all these different cases share the fact of being "in pain" and not something else. How can this (assumed) fact be explained?

Option 1 (of Sec. 2.5 above) is type-type identity reductionism, according to which all the cases of pain *are (identical with)* shared aspects (macrovariables) of the microstate of the creature that feels pain, be it a human being or an octopus or an alien. The shared aspect is *exactly* the same, it is reproduced *precisely* in all the cases in which there is pain (as Putnam 1975 realized from the start). This is the Flat Physicalist account of the mental. Friends of multiple realization of the mental by the physical acknowledge that Option 1 is coherent, but think it is unreasonable (famous examples are Putnam 1975 and Fodor 1974).

Friends of multiple realizability, i.e., of non-reductive physicalism, reject Option 1, insisting that whatever human pain and octopus pain share is not an aspect of their microstate, that is, these cases are *genuinely physically heterogeneous*. They need to opt for either Option 2 or Option 3 (of Sec. 2.5 above)

According to **Option 2** it should be possible to account for this case by introducing an observer that, when any of the heterogeneous cases takes place, is in the brain state in which it "believes that this creature is in pain". But this option raises two problems.
(1) It starts an infinite regress, since the question re-arises concerning the belief of the observer.
(2) It can't work since the octopus and the human being *feel* - directly and intrinsically - that they are in pain, so that this pain must be about *them*, rather than about the *observer*.[20]
So Option 2 is not open to friends of multiple realizability of mental kinds by physical kinds.

We are left with **Option 3**: since the creatures that are said to share the feeling of pain do not share a physical fact, they share a non-physical fact, a non-physical feature that obtains in each and every token of "being in pain". This is token dualism. "Non-reductive physicalism" is a misnomer: an approach that allows for genuine multiple realization is not physicalism at all, but is token dualism.[21]

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[20] Some thinkers deny that first person reports are good evidence concerning the mental realm. We set aside this issue; see Shenker 2020b for references and discussion.

[21] By the way, we propose here that Putnam's famous Twin Earth thought experiment, in which two substances, XYZ and H_2O, causally bring about in the observer the same experience, should be analyzed along these lines, and similarly Kripke's (1980) "theoretical identifications" such as "water is H_2O" (see Hoefer and Marti 2019). Importantly, water is not a mere "Lego"-like composition of particles (see Chang 2012, 2015): the interactions responsible for the existence of each molecule and for their combination to form water are described by the theories of fundamental physics, and form part and parcel of the aspects of the fundamental physical state of affairs that we call "water"; there is no residue that calls for explanation in terms of other metaphysical relations like grounding, determination, realization, etc.

3. The metaphysical framework: The Mentaculus and the Humean base

Having presented The Mentaculus (in Sec. 1) and Flat Physicalism (in Sec. 2) we now return to examine The Mentaculus in some more detail, comparing it with Flat Physicalism. Albert and Loewer work in the framework of a version of a Lewis-style metaphysics concerning laws and chance (see e.g., Albert 2014 pp. 23-24, Loewer 2020a, and especially Loewer's recent "package deal" version in his 2020b). This framework guides the construction of The Mentaculus and explains some of its features. In this section we explore this metaphysical framework.

David Lewis is often seen as one of the most important reductionist philosophers (see for example Weatherson 2016). But it is not clear whether he endorsed metaphysical reductionism in a straightforward way. Hall (2020) writes:

> "What he in fact recommends is a holistic approach: we start with the total body of claims we are inclined to believe - whether on the basis of "common sense" (an oft-invoked category, for Lewis) or of science - and try our best to systematize it in accordance with standards of theoretical goodness that are themselves endorsed by common sense and/or science (and so are themselves, to some extent, also up for grabs). … Here is an especially succinct description of this approach: "One comes to philosophy already endowed with a stock of opinions. It is not the business of philosophy either to undermine or to justify these preexisting opinions, to any great extent, but only to try to discover ways of expanding them into an orderly system." (Lewis 1973, p. 88). Still, while Lewis's method of philosophical inquiry is certainly not "bottom-up", in my opinion it is best to present the results of that inquiry in a bottom-up fashion." (Hall 2020).

And this is the line we shall pursue. To the extent that such a bottom-up description recovers Lewis's main results we would see it as (for all practical purposes) reductionist. It seems to us that Loewer's (2020b) PDA is in line with the holistic spirit that Hall ascribes to Lewis. We shall interpret Loewer's approach and examine its reductive nature along the same lines.

Generally speaking, Lewis's metaphysics can be described as consisting of four main elements, which we describe by bringing four quotations from Lewis (marked (i), (ii), (iii) in Sec. 3 and (iv) in Sec. 4).

> (i) "Humean supervenience is named in honor of the great denier of necessary connections. It is the doctrine that all there is to the world is a vast mosaic of local matters of particular fact, just one little thing and then another. (But it is no part of the thesis that these local

> matters are mental.) We have geometry: a system of external relations of spatiotemporal distance between points. Maybe points of spacetime itself, maybe point-sized bits of matter or aether or fields, maybe both. And at those points we have local qualities: perfectly natural intrinsic properties which need nothing bigger than a point at which to be instantiated. For short: we have an arrangement of qualities. And that is all." (Lewis 1986, pp. ix-x)

Lewis's "vast mosaic", which is "all there is to the world", is often called the "*Humean base*". Loewer's (2020b) PDA introduces substantial amendments to Lewis's conception of the Humean base: both to what the Humean base *is*, and to how we can *know* it. In Lewis's approach the properties of the elements of the Humean base are categorical, and their distribution among the elements is contingent. This contingency is what makes it "Humean". Loewer writes:

> "Most contemporary Humeans … agree with Hume that fundamental necessary connections between distinct entities are metaphysically and epistemologically mysterious and not required by an account of the metaphysics of laws found in science." (Loewer 2020b)

In Lewis's Humean base nothing is necessary about the distribution of the qualities; they just happen to be the way that they are. Several questions arise: What determines the elements of the Humean base? What are they? And how can we know them? We examine Lewis's view on this and Loewer's (2020b) PDA.

First question. In Lewis's account, the qualities of the elements of the Humean base are categorical: brute, unexplained and unexplainable facts. In a sense, nothing "determines" them; they are what they are, and that's the end of it. In particular, they are not defined by any laws governing them: the fact that there are no such laws is, as we said, a key feature of Lewis's Humean base. It is precisely this nature of these qualities that provides Lewis with the possibility of making their distribution completely contingent. But categorical qualities ("quiddities") are considered by many, Loewer (2020b) included, as metaphysically problematic (see e.g. Maudlin 2007b). To avoid them and provide some justification for the postulation of certain qualities rather than others, Loewer (2020b) opts for properties that are characterized under laws. He writes:

> "The PDA is a descendant and I believe improvement over Lewis' [best system approach]. Like Lewis' Humean [best system approach] it rejects governing laws and law determining powers. But unlike Lewis' [best system approach] its account follows more closely the aims of physics and the criteria physicists appeal to in order to achieve them than a priori metaphysics. By rejecting Lewis' reliance on metaphysically given perfectly natural properties while maintaining the basic idea of his [best system approach] the PDA results

in an account of laws and fundamental properties that is friendlier to contemporary physics." (Loewer 2020b)

Loewer acknowledges that this introduces into the Humean base an element of necessity - the very thing that Lewis tried to avoid. But Loewer thinks that this kind of necessity is compatible with the main aims, gist, and principles of a Lewis-style metaphysics. The reason might be that the properties and the laws are parts of the same "package deal", in which the parts impose constraints on one another, but as a whole the package is contingent.

Next questions: What are Lewis's categorical qualities? And how can we know them? For Loewer (2020b), contemporary physics provides a key for discovering the nature of the Humean base, in line with Lewis's following words.

> (ii) "It is a task of physics to provide an inventory of all the fundamental properties and relations that occur in the world...We have no a priori guarantee of it. but we may reasonably think that present-day physics goes a long way toward a complete and correct inventory… And we may reasonably hope that future physics can finish the job in the same distinctive style. We may think, for instance, that mass and charge are among the fundamental properties... we may provisionally accept that all fundamental properties and relations that actually occur are physical. This is the thesis of materialism." (Lewis 1994, p. 412-13)

Notice that for Lewis "the thesis of *materialism*" is subtly different from what is often taken to be the thesis of *physicalism* (or of *materialism* standardly understood). According to physicalism, the world is fundamentally physical, and there is nothing over and above whatever physics describes. According to Lewis, by contrast, the world is fundamentally the Humean base, and physics - which is (part of) the "best system" (a notion discussed in a moment) - is a theory that provides some information about it, that enables useful predictions about the phenomena. We write that physics is "*part of*" the "best system" (and not the "best system" *simpliciter*) because on the approach of Lewis as well as of Loewer and Albert the best system may include additional elements, as we discuss below and in the next section.

Why is physics the key to discovering the properties of the Humean base elements, in Lewis's approach? The answer is that physics is (part of) the "best system" with respect to the Humean base; Lewis writes:

> (iii) "Laws of nature, whatever else they may be, are at least exceptionless regularities. Not all regularities are laws, of course. But, following the lead of… Ramsey, I suggest that the laws are the ones that buy into those systems of truths that achieve an unexcelled combination of simplicity and strength. That serves the Humean cause." (Lewis 1986, p. xi)

Albert and Loewer endorse the general Lewisian framework for understanding laws of nature as "best systems". Albert explains this idea thus:

> "You get to have an audience with God. And God promises to tell you whatever you'd like to know. And you ask Him to tell you about the world. And He begins to recite the facts: … you explain to God that you're actually a bit pressed for time, … And you ask if maybe there's something … that will serve you well, or reasonably well, or as well as possible, in making your way about in the world. And what it is to be a law, and all it is to be a law, on this picture of Hume's and Lewis's and Loewer's, is to be an element of the best possible response to precisely this request - to be a member (that is) of that set of true propositions about the world which, alone among all of the sets of true propositions about the world that can be put together, best combines simplicity and informativeness."[22] (Albert 2014, pp. 23-24)

As Loewer (2020b) emphasizes, in order to quantify the degree of simplicity and informativeness in describing the distribution of the properties among the elements of the Humean base, we need to know *which* those properties *are*. For Lewis, those are "perfectly natural" categorical properties; but which are they?

The "best system" is a theory that bears a particular kind of relation to the Humean base: it *is* (or *contains*) the set of true propositions *about* the Humean base, and this means that if the best system is physics (i.e. assuming that physics contains true statements about the Humean base) then the Humean base has to be *amenable* to such a partial description by physics, and this provides some constraints, and thereby some information, about the nature of the Humean base. As we saw in quotations (i) and (ii) from Lewis tries to make his Humean base amenable to a description by classical physics. But why constrain the Humean base to fit classical physics which is not our best physical theory? Lewis would say that classical physics may give wrong predictions, but (a) some of its fundamental ideas (such as the idea of point-like particles) may be still true; and (b) there are good reasons to think that quantum mechanics in its present form is fundamentally flawed, so we can't take lessons from it about the base, either. Loewer disagrees: for all the reasons for accepting contemporary physics as the best available theory, he wants a Humean base that will be amenable to a description by our best contemporary theories. Therefore, he proposes that the properties of the elements of the Humean base should be those that appear in the laws of contemporary physics (but perhaps not exclusively; see Sec. 4 below on the special sciences).

Damerest expresses the following worry concerning Loewer's approach:

[22] Here we take these latter properties to have objective meanings, so that there is a matter of fact concerning their degree in each "set of true propositions". See on this Weatherson (2016).

> "For the Lewisian Humean, the actual world is made up of a spacetime with perfectly natural properties distributed throughout, and it is this distribution that we systematize with our logical law-statements. However, on Loewer's account, there are no perfectly natural properties—or if there are, they may well be irrelevant to scientific theorizing. So, there is the question of what the world is made up of, fundamentally. What is meant to stand in for the 'Humean mosaic' that other Humeans are happy to posit? What, exactly, do our best logical law-statements - formulated in terms of useful predicates - actually systematize?" (Demarest 2019 p.393)

Loewer's response to Demarest is this:

> "The PDA accomplishes this trick [by requiring] that the optimal package enables accounting for the macroscopic in terms of the microscopic. While macroscopic entities and properties are not fundamental, one of the main aims of physics is to account for macroscopic truths in terms of fundamental properties and laws. This requirement helps nail down the optimal." (Loewer 2020b)

(We are not sure what is meant here: perhaps Loewer alludes to an "account" by multiple realization of the properties and laws of the special sciences (sciences that are "not fundamental", perhaps those are the "macroscopic") by the properties and laws of physics (which is "fundamental", perhaps this is the "microscopic"). We explained the notions of "microscopic" and of microstates and macrostates in physics in Sec. 2 above; in Sec. 4 we discuss the special sciences.)

Lewis's idea (in quotations (i) and (ii) above) was that in order for physics to be able to say something significant about the categorical qualities of the elements in the Humean base, those qualities must appear (at least partly) in physics, and hence from physics we can learn something about the Humean base. Those are the statements of physics that are the "set of true propositions about the world" (Albert 2014, p. 24).

Which "physics" are we talking about? Suppose, with Loewer and Albert, that physics is The Mentaculus:

> "My proposal is that The Mentaculus (with the correct dynamical laws) is the best system for our world." (Loewer 2020a).

(We may assume that here the NM and CF are *placeholders* for contemporary physics, for example: they might be some suitable version of quantum mechanics; and PH and SP are *placeholders* for suitable auxiliary hypotheses.) In order to understand the relations between The Mentaculus and the Humean base it is useful to consider to what extent they overlap.

Are there elements of The Mentaculus that are not in the Humean base?

Loewer (1997) says that there are:

> "[Humean Supervenience] doesn't entail physicalism since it is compatible with there being Humean properties that are not physical. Physicalism doesn't entail [Humean Supervenience] since there is no guarantee that the fundamental properties posited by physics are intrinsic properties of spatio-temporal locations. In fact, it seems pretty clear that contemporary physics does dream of non-Humean properties." (Loewer 1996, p. 103-4)

Here is an example of an element of The Mentaculus that is not in the *Lewisian* (not PDA!) Humean base. In NM - which is part of The Mentaculus - there are velocities (and other time derivatives), and since these entail that the time slices are not independent of each other, as Albert (2000, Ch. 1) emphasizes, the instantaneous velocities, which play an important role in NM, are not elements of the Humean base.

Of course, the fact that there are elements of The Mentaculus that are not part of the Humean base, is by itself not a problem in a Lewisian framework, as long as they are conducive to the overall "best system" balance between simplicity and informativeness *about* the world, that is, *about* the Humean base.

On the other hand, this raises the following problem: *How* do we know that (or whether) velocities, for example, are not in the Humean base? We know that if we are sure that the elements of the Humean base are independent. But how do we know *that*? *For Lewis* some criterion for this is provided by the motivation for coming up with the whole Humean framework, namely, eschewing the notion of necessity from the fundamental metaphysics. (We address Loewer's PDA in a moment.) But while this Lewisian motivation may help with respect to deciding whether or not velocities are in the Humean base, it is less helpful in other cases. Here is an example. Consider an "upgraded" version of The Mentaculus in which NM is a placeholder for some version of quantum mechanics in which the quantum state is interpreted realistically. This requires a non-trivial *alteration* of Lewis's description of the Humean base. Loewer writes:

> "The lesson for a defender of [Humean supervenience] to take from quantum mechanics is to count a property as Humean in a world iff it is an intrinsic quality of points in the fundamental space of that world. If Bohm's theory (or any other version of QM that construes the wave function realistically) is correct then that space is configuration space. Given this account of Humean properties quantum non-locality poses no threat to [Humean supervenience]." (Loewer 1996, p. 104)

But this lesson is controversial. For example, Dürr, Goldstein and Zanghi (1992) argue that the wavefunction in Bohmian Mechanics is not a physical state of anything, but rather a law defining the motion of particles, since it is defined over the high-dimensional 3N-configuration space, which they take to be a state space (of all possible Bohmian positions), not the real physical space. Albert (2014) criticizes this view arguing that the wavefunction in the 3N space is (in John Bell's words) "a physically real field, as real here as Maxwell's fields were for Maxwell." (Albert 2014, p. 126, quoting Bell 1982). This idea, however, violates features of the space of elementary events proposed by Lewis.

So, there are elements in The Mentaculus that are not in the Humean base: in order to provide the "best" system that balances informativeness and simplicity, The Mentaculus includes a partial description of the Humean base as well as additional elements. But does a "best system" *have* to be like that? Couldn't there be a "best system" that consists only of a partial description of the Humean base with no additional elements? As the Humean base becomes closer to physics (and vice versa) the whole metaphysical framework becomes closer to physicalism, as for example in Flat Physicalism. Will the in-principle difference between these metaphysical frameworks cease to be interesting at some point? We leave this question open.

Are there elements of the Humean base that are not in physics?

Trivially there are elements of the Humean base that are not in physics, since if physics is to be a "best system" that *balances* simplicity and informativeness, it will in general not provide the full information about the Humean base (as is made clear in Albert's parable above).

But more generally, are there elements of the Humean base that *cannot* (in principle) be accounted for by physics? To answer this question, it is important to distinguish between two approaches to the term "physics":

(1) "Physics" is the *entire* Mentaculus, where CF+NM may be placeholders for contemporary physics, and PH and SP may be placeholders for suitable *auxiliary* hypotheses. PH and SP are included in The Mentaculus since it is assumed that they *cannot* be deduced from CF+NM. So here, the corresponding elements of the Humean base can be deduced from "physics" *qua* The Mentaculus, but not from "physics" *qua* CF+NM.

(2) "Physics" is *only* CF+NM, where again those are placeholders for contemporary physics, and PH and SP (or the statements for which they are placeholders, if they are true,) are derived from CF+NM. Flat Physicalism is a theory of this structure (as we saw in Sec. 2.3 and 2.4).

In each of these two cases the question of whether there are elements in the Humean base that are not in physics may be different.

In Lewis-style metaphysics, "physics" is (part of) the "best system", and therefore the question of which of option (1) or (2) is "physics" depends on the question which of them is at least "better", if not the "best". *If* there is a theory of kind (2) which provides the same degree of informativeness with respect to the Humean base as The Mentaculus does, *then* it is "*better*", at least in the sense of "best system", than The Mentaculus which is a theory of kind (1). It seems to us that both Albert and Loewer accept this idea for which theory would be "better". For example, Albert (2000, Ch. 7; 2014, Ch. 1) argued that his "GRW Mentaculus", in which NM is replaced with the collapse theory by Ghirardi, Rimini and Weber (1986; see also Bell 1987), is better than the classical Mentaculus (or any other quantum theory), since given a certain hypothesis he introduced about the GRW dynamics, the Second Law probabilities are reduced to the Born probabilities, without assuming any probability distribution over quantum states. The GRW Mentaculus is better presumably because it gets closer to a kind (2) theory.

Flat Physicalism is a theory of kind (2): as we saw in Section 2 it assumes only CF+NM (seen as placeholders for our best fundamental theory of physics) and it accounts for PH, for SP, for the notion of objective chance in a deterministic universe, and for the special sciences including psychology, all on the basis of CF+NM. Relative to Flat Physicalism, The Mentaculus is not the "best system".

4. The Mentaculus and the special sciences

In the previous section we addressed the relation of "best system" between The Mentaculus and the Humean base. This is not a reductive relation, in any of the directions, and moreover we expressed the view that The Mentaculus is not the "best system" of the Humean base, and that there is a "better" one: Flat Physicalism. In this section we set this relation aside and turn to another question concerning The Mentaculus: suppose that we take The Mentaculus to be our "physics" (type (1) theory in the terms just discussed in Sec. 3). Given this assumption, according to the metaphysical framework endorsed by either Lewis or Albert and Loewer, do all the phenomena and facts in the universe, and in particular those described by the special sciences, reduce to - or are otherwise accounted by - The Mentaculus? *In this sense: Is everything "physical"?*

Albert writes on this matter:

> "... the special sciences must all, in some principled sense, be deducible from the fundamental laws of physics." (Albert 2014, p. 10)

Let us clarify **(a)** what these "fundamental laws of physics" are, and then **(b)** what those "special sciences" are, and are they indeed "deducible" from the former in the account of Loewer and Albert.

(a) The fundamental laws are, for Albert and Loewer, The Mentaculus (i.e., all of its elements, not only CF+NM):

> "If anything along the lines of the picture we are trying to imagine here should turn out to be true, then any correct special-scientific explanation whatsoever can in principle be uncovered, can in principle be descried, in the fundamental physical theory of the world, by the following procedure. Start with The Mentaculus. Conditionalize The Mentaculus on whatever particular features of the world play a role in the special-scientific explanation in question - conditionalize The Mentaculus (that is) on whatever particular features of the world appear either explicitly or implicitly among the explanantia of the special-scientific explanation in question. And check to see whether or not the resultant probability distribution - the *conditionalized* probability distribution, makes the explanandum *likely.* If it does, then we have recovered the special-scientific explanation from the fundamental physical theory - and if it *doesn't,* then either the fundamental theory, or the special-scientific explanation, or both, are *wrong*." (Albert 2014, p. 17)

(By the way, Albert endorses here the idea that showing that a certain fact is likely explains why this fact obtains. *If* (as we believe) the SP of The Mentaculus involves assuming a probability measure just because it makes the actual facts likely, *then* the SP cannot explain why those actual facts obtain. This point is crucial with respect to some of the typicality arguments, see Hemmo and Shenker 2012, 2015b; we do not expand on this issue here.)

(b) What does The Mentaculus explain? What are the special sciences and how are they explained by The Mentaculus? It seems to us (we are not sure) that on this matter, in particular with respect to multiple realization, Loewer's and Albert's views may differ, and therefore we address their views separately.

4.1 Loewer's view

Loewer says that The Mentaculus is "arguably a complete scientific theory of the universe" (Loewer 2020a p.6), but then he adds:

> "The Mentaculus provides an account not only of the laws of thermodynamics, but also an important *ingredient in* an account of *other* special science laws." (Loewer 2020a p. 12; our italics)

Importantly, for Loewer The Mentaculus is sufficient to account for the laws of thermodynamics, but *not* for "*other* special sciences": there, it is only an *ingredient* in the account. Why is that so?

We suspect that the reason for this is that Loewer accepts that the special sciences are *not* deducible from The Mentaculus, because on his view special sciences properties are multiply realizable by physical properties. In earlier writings Loewer (2008) endorsed multiple realizability *explicitly*. He expressed the "*physicalism*" element in "non-reductive physicalism" thus:

> "Question: ''Why is there anything except physics?'' Answer: ''Because there is physics!''" (Loewer 2008, p. 162)

And expressed the "*non-reductive*" element in "non-reductive physicalism" thus:

> "It is true that the account of special sciences I have described … isn't reductionist in some other ways. It doesn't entail that special science properties are identical to properties of fundamental physics and it allows for the multiple realizability, temporal asymmetry and so on of special science laws." (Loewer 2008, p. 162)

In this Loewer followed the footsteps of Lewis:

> (iv) "My reductionism about the mind begins as part of an a priori reductionism about everything… the very same fundamental properties and relations, governed by the very same laws occur in the living and the dead parts of the world, and in the sentient and the insentient parts, and in the clever and the stupid parts. … When we describe mental state M as the occupant of the M-role,... [i]t says nothing about what sort of state it is that occupies the role. It might be a non-physical or a physical state, and if it is physical it might be a state of neural activity in the brain, or a pattern of currents and charges on a silicon chip, or the jangling of an enormous assemblage of beer cans." (Lewis 1994, p. 412-3, 418; see also Lewis 1966, 1980a)

In Sections 2.5 and 2.6 above, when we discussed the Flat Physicalist account of the special sciences, we showed that allowing for multiple realizability amounts to endorsing token dualism, that is, endorsing the view according to which *not* everything is physical, and in the present context, that not everything is deducible from The Mentaculus. *To the extent* that Loewer accepts the multiple realizability thesis, he endorses a dualist metaphysics, in which indeed The Mentaculus is at best an *ingredient* in accounting for the special sciences. While Lewis acknowledges that both supervenience and multiple-realizability are not a priori requirements, he takes them to hold as a matter of fact in our world, and in this sense, *Lewis endorses a dualist metaphysics*, whatever his "physics" is and whatever his account of the Humean base is.

Notice that the "non-physical" facts, that must be assumed as part of the multiple realizability thesis, need not be supernatural facts; they are merely non-physical ones, that is - in our context - *not in The Mentaculus*. Whether the "best system" laws, that optimally balance informativeness and simplicity with respect to the Humean base, turn out to describe a world that is *unified* in being reducible to "physics", or turn out to be some *patchwork*, is a question of fact. Presumably, however, if a theory according to which everything is "physical", and a theory according to which some things are "physical" and some are not, provide comparable informativeness, we conjecture that the wholly physical one will be "better", in the sense of "best system". In this sense it seems to us that Flat Physicalism is "better" than The Mentaculus *á la* Loewer, due to its account of the special sciences.

Notice that for Loewer, in the above quotation, The Mentaculus does provide a full account of thermodynamics, unlike the "other" special sciences (he takes thermodynamics to be a special science, albeit with a special status). The reason might be that all the facts that are needed to account for thermodynamics, have been inserted by hand into The Mentaculus: this is why it includes PH and SP in addition to NM and CF. We are not sure why thermodynamics merits this special treatment: Why insert into The Mentaculus only the facts that explain the special science of thermodynamics, and not the facts that explain the other special sciences? In Flat Physicalism, at any rate, all the special sciences are on a par and are given the same analysis and the same explanation.

Why does Loewer require *supervenience* of the special sciences kinds on the physical kinds, in his "best system"? In the literature it is often said that supervenience expresses the primacy of physics, that many accept (e.g. Kim 2012; Davidson 1993), but in the "best system" approach this criterion is secondary, or even irrelevant: *the sole criterion* for being a system of laws of nature is whether or not the system is "best" in providing the optimal balance between informativeness and simplicity. Whether requiring supervenience while allowing for multiple realization is "best" in this sense we are not sure. Our Flat Physicalism, at any rate, requires supervenience as part of its reductive physicalist principle, and because of the primacy it gives to physics, and its commitment to there being nothing over and above the physical, it rejects the multiple realizability thesis.

In sum, the situation for Loewer seems to be this. CF+NM cannot account for any of the special sciences. To account for thermodynamics, you need to add the extra facts (auxiliary hypotheses) of PH and SP. Those are declared to be part of The Mentaculus. But because of *multiple realization* to account for other special sciences one needs *additional* extra facts, and those are not made part of The Mentaculus. We are not sure why this distinction between thermodynamics and the other special sciences is made in Loewer's approach. In Flat Physicalism (see Secs. 2.3-2.6) all the special sciences are on a par, and all are derivable from CF+NM.

4.2 Albert's view

Albert, unlike Loewer, thinks that "something's funny" about the idea of multiple realizability. He brings two arguments by way of examples; let's analyze them briefly, by comparison with Flat Physicalism.

As we saw (in Sec. 2.5 and 2.6) Flat Physicalism identifies special sciences properties with aspects (macrovariables) of microstates, stressing that at each moment everything that exists, and therefore everything we observe, is the *actual particular* microstate (or the actual particular sequence of microstates), and with it of course its aspects. This is the ontology. Epistemologically, if everything that we know about the actual microstate is one of its aspects, and we remain ignorant about the rest of the aspects, then we cannot distinguish between the actual microstate and a continuous infinity of counterfactual microstates that have the same aspect, and the set of these indistinguishable microstates, all but one of which are counterfactual, is the macrostate. This set is a theoretical construct and is not "out there in the world".

By contrast, Albert (2014) identifies features of the world that are described by the special sciences, with *sets* of microstates. He writes:

> "Those explanantia [i.e., the features of the world] are initially going to be given to us in the language of one or another of the special sciences. And so, in order to carry out the sort of conditionalization [i.e., the account in terms of The Mentaculus] we have in mind here, we are going to need to know which of those special-scientific explanantia correspond to which *regions* of the space of possible exact physical microconditions of the world. And those correspondences can be worked out - not perfectly (mind you), but to any degree of accuracy and reliability we like - by means of the super-duper computational techniques alluded to in Section (i)." (Albert 2014 p. 17 footnote 4; our emphasis)

(The "super-duper computation" is akin to Laplace's Demon.) Note that Albert's identification of special science magnitudes with sets of microstates (that occupy state space regions) is unclear and somewhat ambiguous. Supporters of multiple realization agree that by following the equation of motion for each initial state the super-duper computer can work out which "special science explanantia" correspond to which phase space regions of possible microstates. But what they reject is that the super-duper computer will find a *single macrovariable* (not disjunctive!) that is shared by the microstates in all those regions corresponding to the same special science kind (that figures in the "explanantia"). Obviously, if there is such a type-type-mapping between macrovariables and special sciences kinds, the super-duper computer will find it, and then the multiple-realization thesis will break down. With this point in mind, let us now proceed to examine Albert's argument against the multiple realizability thesis.

To illustrate his objection to the thesis of multiple realizability Albert describes the following example concerning the "science of epidemiology":

> "There are … physical systems in the world ... which are capable of distinguishing, in a more or less reliable way, under more or less normal circumstances, between those possible fundamental physical situations of the universe in which there is (say) a flu going around, and those in which there isn't. And so there must be a fully explicit and fully mechanical technique for coordinating epidemiological situations with their fundamental physical equivalents - or (at any rate) for doing so in a more or less reliable way, under more or less normal circumstances - because there are (after all) mechanical devices around, right now, that can actually, literally, get it done." (Albert 2014, p. 10)

To understand this argument, we need to recall that when discussing the Flat Physicalist account of the special sciences we distinguished between three options. Applied to the flu example, **Option 1** says that several cases are all of the kind "flu" because there is an *aspect* shared by the microstates of the observed systems "out there", and it is this aspect that is (identical with) flu. The epidemiologist interacts with this aspect in each and every one of the cases, and thereby comes to have the brain state in which she believes that it is a case of flu. In Option 1 there is no multiple realization; it is the option of reductive type-identity physicalism.

According to **Option 2**, by contrast, the microstates "out there" do not share any physical aspect; they are physically heterogeneous, and nevertheless there is a system called "the epidemiologist" that comes to have the brain state in which she believes that it is a case of flu. The brain state of the epidemiologist does not measure the systems "out there" since those do not share anything that will make them a kind. What makes them a kind is only the shared brain state of the epidemiologist: If we *extend* the microstates to include not only the systems "out there" but also the brain of the epidemiologist, then the extended systems' microstates *do* have a physical aspect in common, namely, the brain state of the epidemiologist. Here, we stressed, the epidemiologist does not *discover* the special science kind of flu, but *creates* this kind. Option 2, when we consider the extended microstate, is also not one of multiple realization, and is also explained as a case of reductive type-identity physicalism. Cases of Option 2 may *appear* to be ones of multiple realization, if we ignore the epidemiologist and consider only the systems "out there". This is *apparent but non-genuine* multiple realization.

Option 3 is the case of *genuine* multiple realization, and this - we argued - is a case of token dualism.

In these terms, Albert's above example illustrates cases compatible with reductive type-identity physicalism, in which special sciences kinds are *not* multiply realized by physical kinds, and so this example does not give rise to an argument about (or against) multiple realization. It seems that

Albert mainly talks about Option 1, in which the epidemiologist detects the physical aspect that is shared by all the tokens in which there is a flu - this is clearly a case of reductive type identity physicalism. He does not point out that in Option 2 there might be an apparent but not-genuine multiple realization, and does not address Option 3 of genuine multiple realization. The argument we outlined against Option 3 (in see Sec. 2.5 and 2.6) shows that genuine multiple realization amounts to token dualism, and is therefore not a form of physicalism.

Another argument that Albert brings against the thesis of multiple realizability concerns the law of conservation of energy: here "multiple realization" would mean that different quantities, in worlds with even radically different physical laws than our own, satisfy the same kind of regularity, described and explained by Noether's theorem. Albert writes:

> "We know that the conservation of energy is a law of the actual world - and that is manifestly a substantive and interesting and altogether nontrivial claim. But outside of that, all we seem to know is that the principle is a law in all and only those worlds whose fundamental laws share this particular feature (that is, the feature of entailing the conservation of energy) with the actual one. All we seem to know (to put it slightly differently) is that the principle is a law in just those worlds in which it is a law - which is not to know anything, at least of an empirical kind, at all." (Albert 2014 p. 14-15)

Notice that this kind of multiple realizability is not the one envisaged by Fodor (1974, 1997), and addressed recently by for example Polger and Shapiro (2016), for they - as most of the contemporary philosophers of science and of cognitive science - seem to have in mind multiple realizations in our world. (Putnam 1975 may have other-worldly cases in mind as well.) Here Albert says that the counterfactual cases he imagines share the feature of "satisfying this law", but we don't know why they do; we don't know which features of them make it the case that they do. However, if, in the end, we shall discover (theoretically, of course) which feature those counterfactual worlds share, in virtue of which they all satisfy the law of conservation of energy, then this will be a case of **Option 1** above, in the following sense. This shared feature would be described in terms of some "super-physics", in which all these worlds can be described. (Lacking such a super-physics language we are not sure how to make sense of this example.) Option 1 here would mean that the different worlds share a super-physical aspect.

But it seems that this is not what Albert has in mind, since he writes:

> "[T]he conservation of energy can obviously be *realized*, the conservation of energy can obviously be *underwritten*, by any number of distinct sets of fundamental laws of physics—laws which will in many cases be radically different, in any number of other respects, from our own." (Albert 2014 p. 14-15)

The other options are the following. If, in the end, we shall discover (theoretically, of course) that those counterfactual worlds do not share anything super-physical, then their shared satisfaction of this law (if it is describable at all!) would be a mere coincidence, and in fact they will not be exhibiting the same law at all: they will be satisfying different laws, with some parallel *structural* features. This might be understood as **Option 1** as well, where the shared feature is the structural one, or it can be understood as **Option 2**, where the shared feature is the theoretician's belief (i.e. brain state). **Option 3** would mean that these counterfactual worlds do not share anything physical, or super-physical, or something in the theoretician's brain. This would mean that we have super-physical token dualism.

In sum, Albert has the intuition that the thesis of *multiple realization* is unacceptable, but his discussion does not offer an argument against this thesis. We offered such an argument in Sections 2.5 and 2.6.

5. Conclusion

We have argued that Flat Physicalism is a better system of our world in the Lewis-style sense of the term than The Mentaculus, because it is more reductive and more physicalist.

In The Mentaculus, the PH+SP are not derived from the microscopic dynamics of our world given by CF+NM, but are *added* as independent laws about counterfactual worlds. In addition, The Mentaculus is not physicalist, *if* multiple realizability of any of the special sciences by heterogeneous facts is accepted. This holds also with respect to the relation between thermodynamics and fundamental physics (see the example of temperature in Sec. 2.5). As we mentioned, Lewis endorsed multiple realizability as part of his functionalism about the mind. This means that Lewis's view is not physicalism at all, but (as we showed) *token dualism.* We are not sure what are the current positions of Albert and Loewer on this matter.

By contrast, Flat Physicalism is fully reductive and physicalist. It accommodates the fact that given CF+NM, it is possible that PH+SP are false, but if they are true, we have shown how to account for the facts they describe on the basis of CF+NM alone. Likewise, Flat Physicalism accommodates the fact that the Second Law of thermodynamics is *not* a general theorem of mechanics. But: if it is true of our world (i.e., our micro-trajectory), as seems to be suggested by our experience, then this fact can be accounted for on the basis of CF+NM alone. Similarly, the account of all the other special sciences on the basis of CF+NM is fully reductive by Flat Physicalism which is a strict type-type reductive *identity* theory. All the special sciences kinds are strictly identical with physical kinds (aspects of the micro-trajectory) and there is no multiple realization whatsoever. We have shown (see Sec. 2.5 and 2.6; and elsewhere (see Hemmo and Shenker 2015a; 2019b; 2020b) that supervenience of higher-level kinds on physical kinds is not enough, since it is compatible with multiple realization, which in turn *entails* dualism. The laws of the special sciences (if true) are derivable from CF+NM via the probability rule (1) in the same way that the Second Law is.

Let us reiterate that within the Humean "best system" approach token dualism is not to be rejected as such: the only criterion for endorsing or rejecting dualism is whether the laws of nature turn out to be the "best system" in providing the optimal balance of informativeness and simplicity with respect to the Humean base. Still, if The Mentaculus turns out to be a token dualism view, it is of interest to know that this is the case.

Finally, the general question of whether the "best system" of our world is fully reductive in the sense that it consists only of a partial description of the Humean base with no additional elements, and in particular whether this partial description is purely physicalist, is ultimately a question of fact. As the Humean base becomes closer to physics (and vice versa), the whole metaphysical framework becomes closer to physicalism, as for example in Flat Physicalism. Will the in-principle difference between these metaphysical frameworks cease to be interesting at some point? We leave this question open.

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