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INTRODUCTION BY THE GUEST EDITORS: LAWS OF NATURE: METAPHYSICS AND EPISTEMOLOGY

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The debate on the metaphysics of laws of nature is one of the many disputes in the metaphysics of science that emerged in the last decades of the 20th century. It is historically rooted in the discussions on the role of Divine will in the governance of natural phenomena, held during the 16th to 18th centuries. However, its most immediate antecedent is a pressing point in the agenda of the Received View: the task of settling a distinction between authentic scientific laws and mere accidentally true generalizations. In this context the discussion was mainly about the logical, semantic, and syntactic properties of lawlike statements that could underpin the distinction. Conversely, the current debate on the metaphysics of laws presupposes that mere linguistic or logical considerations are insufficient to draw that distinction and something else is needed. That *something else* is frequently a feature of the world that falls under the domain of metaphysics, a law of nature, as opposed to a scientific lawlike statement. Not every position in the debate would happily admit that laws are something *in* the world, but all of them agree that some metaphysical theorization about the world's structure is needed in order to settle the distinction between laws and non-laws.

There are three main frameworks to account for the metaphysics of laws: Humean supervenience, the governing views, and dispositionalism. According to Humean supervenience, there is nothing *in* nature that can be regarded as a natural law. Laws of nature are supposed to bear some degree of (natural, physical, or nomological) *de re* necessity, and Humeans deny any form of necessary connection in nature: there is just a mosaic of causally inert (instantiated) categorical properties—i.e. particular matters of fact—, in Lewis words, *one little thing and then another* (1986: ix). So, if laws are understood in a robust metaphysical sense, Humean supervenience is a version of anti-realism about laws. If anything is to count as a law of nature (in a deflated sense), it must be regularities in the Humean mosaic. However, even when

the regular, non-necessary arrangement of properties is all there is, there is still room for a distinction between authentic scientific laws and mere accidentally true generalizations. The trick is made by appealing to the idea of an optimal systematization of all the world's facts. The most popular and developed version of this idea is the Best Systems Account (BSA) (often referred to as the Mill-Ramsey-Lewis account). According to this view, not every regularity is a law, just the ones described by the axioms (and theorems) of the best systematization of the world that combines (and balances) simplicity and strength. In that manner, no commitment with *de re* modality is needed in order to account for the laws, and for the regular intuitions we hold about them (cf. Loewer 1996).

On the other hand, governing accounts have a realist take on laws. These positions are metaphysically more inflated, since its proponents accept the existence of necessary connections in nature *in the form of laws of nature*. They impute Humeanism, among other disgraces, of lacking explanatory power regarding many important issues such as the relationship between laws and their instances (e.g. Armstrong 1983: 41), the factuality of uninstantiated laws (Brown 1994: 98), and the efficacy of inductive reasoning (Armstrong 1983: 52). In a nutshell, Humeanism lacks a proper explanation of natural regularity. According to the most celebrated version of the governing view, the so-called DTA (for Dretske, Tooley, and Armstrong), laws are complex entities constituted by a second-order universal (a relation of nomic necessitation) instantiated in two first-order universals (natural properties). Thus, a law looks like this: $N(F, G)$, where F and G are natural properties, and N is a relationship of nomic necessitation. Those complex entities are instantiated in (and govern) particular *states of affairs* (i.e. particulars instantiating universals). So we have: $(N(F, G))$ (a's being F, a's being G), what should be understood as: *something's being F necessitates that same something's being G, in virtue of the universals F and G*.

Finally, according to dispositionalists, this complicated metaphysics is too robust. For them, natural regularities are explained by fundamental, sparse, powerful properties, without any need for real laws of nature —at least not as independent entities—. They join the governing views team in pointing out that Humean supervenience lacks explanatory power, but they think that intrinsically modal self-governing properties can perform all the work for which we thought laws were needed, with much less metaphysical cost (e.g. Mumford 2004, Bird 2007). In a few words, regularities are not enough, but universals are just too much. Recently, Demarest (2017) has argued that dispositionalism is compatible with the BSA. In her view, the best scientific package is anti-Humean in its ontology, since it admits the modal (dispositional) character of fundamental properties. However, when it comes to laws, a Humean systematization of such dispositional properties is enough to account for the nomological (cf. 2017: 38).

The papers of this special issue aim to explore new perspectives in the philosoph-

ical studies on laws of nature, with a particular focus on the relationship between the metaphysics and epistemology of laws.

Barry Loewer addresses in detail a long-standing objection to Humean supervenience (directed specifically to the BSA) according to which it fails to give an account of the explanatory power of laws. Objectors in this line claim that Humean laws (Loewer calls them L-laws, after David Lewis) cannot properly explain their instances nor the patterns that they constitute. On the contrary, governing laws (G-laws) are thought to account for the role of laws in scientific explanations by virtue of their governing role. Loewer explores and questions the various forms that this objection has taken in the recent literature. He concludes that worries about L-laws lacking explanatory power disappear when considering the proper notions and distinctions, for example, the one between *scientific explanation* and *metaphysical explanation*. L-laws are explanatory in the sense of scientifically explaining events in the Humean mosaic, while the Humean mosaic metaphysically explains that a generalization is an L-law. Pretending that L-laws metaphysically explain their instances is begging the question against the BSA.

Heather Demarest explores the different metaphysical approaches that can be adopted when using possible worlds to account for the laws of nature. Although the possible worlds apparatus is typically the Humeans' choice when it comes to articulate philosophical accounts of the laws, Demarest persuasively shows that (and how) it is compatible with anti-Humean metaphysical frameworks. She uses *The Mentaculus*—a recent view on laws developed by David Albert and Barry Loewer—as a case study. The Mentaculus is, in a nutshell, a set of possible worlds defined by constraints on the possible macrostates (macrostates that begin with very low entropy) and microstates (those compatible with the initial macrostates), that (ideally) permits a uniform probability measure over worlds. Demarest argues that different metaphysical approaches can lead to different ways of constraining the initial states and defining what counts as a possible evolution of those states. Also, there can be significative variations of the kind and "amount" of metaphysical commitments regarding the status and nature of possible worlds (even among Humeans!).

Luiz Henrique de Araújo Dutra redefines the notions of *scientific law*, *causes* and *powers* within the framework of *perspectival realism* and *emergentism*. He characterizes emergent phenomena as consequences of the complexity of reality, so that our knowledge of emergent objects and processes does not deductively follow from knowledge of their base conditions. These considerations entail perspectival realism, for the occurrence of an emergent phenomenon (such as color vision) depends on certain base conditions, not being reducible to them neither being purely subjective though. In order to explain this kind of process, de Araújo Dutra resorts to Mill's notion of heteropathic laws, which do not follow strictly from the Composition of Causes Principle. Thus, an emergent phenomenon can be simultaneously regarded

from the perspective of their base conditions and the laws valid in its domain or from the emergent perspective and its own realm of laws. Still, de Araújo Dutra argues that the base conditions do not cause the emergent phenomena, neither is it necessary to resort to some mysterious notion of power to explain this process, except as an ontological residue within an open ontology.

Cristian Soto and Otávio Bueno argue that great part of the literature on laws of nature focuses on metaphysical aspects, leaving aside a fundamental task for understanding laws in scientific practice, namely, to provide an account of the mathematical character of physical laws. In order to come up with an explanation of the application of mathematical structures to the physical domain, the authors introduce the *inferential conception of physical laws*, which is largely inspired on the *inferential conception of the application of mathematics*, proposed by Bueno and French. Soto and Bueno present the framework of the inferential conception in three steps: first, some structures of physical domains are *immersed* in a suitable mathematical structure; then, the mathematical formalism allows us to draw *inferences* about the target domain; finally, the mathematical space of possibilities found in the second step must be physically *interpreted*, so that it is possible to distinguish physically uninformative inferences from the informative ones. In addition to outlining their account, Soto and Bueno hold that their view can account for common drawbacks faced by most of the theories on laws.

Nélida Gentile discusses and criticizes some of the most important conceptions of laws of nature. In close dialogue with the recent literature on the subject, Gentile presents some drawbacks faced by the regularity view of Mill–Ramsey–Lewis, by Armstrong's necessitarian view and by Mumford's realist lawlessness. Although the regularity view has the merit of requiring a very austere metaphysics, it lacks a criterion to identify laws of nature, instead of merely scientific laws. On the other hand, the necessitarian account faces a related but reverse problem, because its robust metaphysics leaves no room for a practical criterion to discriminate genuine scientific laws from merely hypothetical generalizations. Following this line of reasoning, Gentile criticizes Mumford's account according to his own terms. Basically, she shows how Mumford's modal realism faces the same difficulties that he imputes to the opponent views. Finally, inspired by the *New Hume* interpretation, Gentile presents her quasi-regularist account, in which the regularities play a central role in identifying laws while leaving room for a noumenic foundation for regularities.

Billy Wheeler outlines his version of the algorithmic theory of laws and responds to some objections to this account. In particular, Wheeler addresses some arguments according to which the universe as a whole is incompressible. Since the algorithmic theory of laws states that laws of nature consist of the algorithms which best compress empirical data about the universe, the hypothesis of the incompressibility of the universe might undermine this account. Wheeler discusses the objections in

three clear steps: first, the claim that empirical data is algorithmically random, so that only processed (and not raw) data can be compressed; the following two steps concern the charge that it is impossible to compress information about chaotic and quantum phenomena because of the way these systems evolve. Discussing all these issues, Wheeler responds to the objections in a clear and detailed manner. Therefore, he concludes that none of these arguments pose real challenges to the algorithmic theory of laws, which stands as an attractive account of laws that ought to receive more philosophical attention.

Ferenc Huoranszki deals with the contingency of laws of nature. In particular, he criticizes the contemporary Humean accounts of contingency, based on the idea that the first-order properties which compose the Humean mosaic could be indiscriminately recombined, giving rise to different laws. He argues that this theory is empty, for it does not explain how the first-order properties should be effectively recombined. Besides, Humean conceivability argument does not concern the contingency of laws in the sense contemporary Humeans take it. Rather than contradicting the practice of assigning modal properties to objects, the conceivability argument supports this practice, for it shows that objects can change in ways not captured by their mere sensible qualities. Still, Humean rejection of modal properties comes from the fact that we have no impression of them. Thus, Huoranszki holds that the contingency of laws is bonded to macroscopic phenomena, since we can conceive objects as having different modal properties on this level. If the laws of nature are contingent, they are so because of the contingency of the manifest world. It is a highe-order phenomenon.

Alexander Maar investigates four different senses of "determinism" in philosophy of science, distinguishing sharply the metaphysical from the epistemic consequences involved in each one. Following Kellert's classification, "determinism" may mean: (i) a property of models that represent the evolution of physical systems through differential equations; (ii) an ontological theory stating that the world (or some system) evolves according to a unique trajectory; (iii) a presupposition that every quantity has an exact value attributed to it; (iv) a thesis concerning the perfect predictability of the states of a system given the knowledge of the relevant laws and initial conditions. Thereby, Maar emphasizes that a great part of the philosophical literature on determinism conflates the ontological version of determinism expressed by (ii) with concerns involving predictability, as presented by the layer (iv). In order to hold that determinism as an ontological account is defensible, even in face of the falsehood of (iv), Maar analyses possible challenges to determinism within chaos theory and quantum mechanics, concluding that the difficulties brought up by both theories relate only to the epistemic sense of "determinism", not to its ontological aspect.

Finally, Damian Fernandez Beanato presents a review of *The Metaphysics of Science and Aim-Oriented Empiricism*. In this book, Nicholas Maxwell maintains his ro-

bust account on philosophy of science, based on three main theses: physical essentialism, experiential physicalism and aim-oriented empiricism.

One of the primary motivations for this project is to bring together the work of researchers from Latin American and non-Latin American countries on the metaphysics of science. The first five articles of this Special Issue were contributed by six invited authors, three of them working in Latin American Universities (Luiz Henrique de Araújo Dutra, Federal University of Santa Catarina, Brazil; Cristian Soto, University of Chile, Chile; and Nélida Gentile, University of Buenos Aires, Argentina), and three based in the United States of America (Barry Loewer, Rutgers University; Heather Demarest, University of Colorado Boulder; and Otávio Bueno, University of Miami). We thank them for kindly accepting our invitation to participate in this volume. We also thank Billy Wheeler, Ferenc Huoranszki, Alexander Maar, and Damian Fernandez Beanato for their valuable contributions.

Barry Loewer and Heather Demarest deserve a special, extra mention. The idea of organizing a volume integrating the work of Latin and North American researchers on the metaphysics and the epistemology of laws came up during the CEU-Summer University "The History and Metaphysics of the Concept of Laws of Nature", held in Budapest at Central European University, in July 2018. Barry organized that outstanding event that had Heather as one of the Course Faculty. Without them on board this volume would not have been possible.

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