Philosophica 92 (2017) pp.5-11

INTRODUCTION

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1. Strong Emergence

This special issue is focussed on questions concerning the ontological debate between emergentists and reductionists. Strong emergentists typically hold that at least some higher-level phenomena exhibit the following features:

Distinctness: the emergent entity must be something *different* from the 'base' entities from which it emerges.

Novelty: the emergent entity must be *novel with respect to* its base; although it needn't be novel in some absolute sense, that is, it needn't be the first individual entity of its kind to exist. This novelty must be more than additive/aggregative novelty: the mass of a one kilogram sample of sugar is distinct from the masses of each of the granules which constitute it, but it is easy to see how the mass of the whole sample is merely an aggregate of the masses of its members. The combination of *novelty* with *distinctness* perhaps captures the sense of the locution 'over and above', which is often used to describe the relation emergent entities bear to the base entities from which they emerge.

Dependence: there is some relationship of dependence between the emergent entities and the base entities from which they emerge. This dependence should be asymmetric: it shouldn't also be the case that the basic entities depend on the emergent entities. It should also be existential in nature: the emergent entities would not exist without the base entities.

Weak emergentism, in contrast, holds that the truths concerning high-level phenomenon are unexpected given the principles at the lower domain (see, for instance, Chalmers 2006), and is often seen as being of primarily *epistemological*, as opposed to ontological, importance (see Carruth and Miller 'Strong Emergence' in volume 1 for a more detailed introduction to the topic).

This special issue aims to clarify a range of issues concerning what the claim that there are strongly emergent phenomena commits us to, and to investigate the plausibility of certain candidate examples of strong emergence. The papers therefore take up both theoretical and empirical questions around the possible existence of strong emergence. This intersecting of the theoretical and the empirical is especially important in the case of debates about emergence. This is because many of the supporters of emergence draw their belief in emergence from the apparent examples of emergent phenomena: that is, phenomena that, it is claimed, cannot be explained if we adopt alternative views about the nature of reality. The papers in this issue embrace this interdisciplinary enterprise.

In volume 1 of this special issue, Elanor Taylor addresses questions concerning the relationship between explanatory emergence and metaphysical structure; Umut Baysan and Jessica Wilson discuss the 'collapse' objection to strong emergentism; James Miller examines whether there may be strongly emergent linguistic properties, and Michael Silberstein argues that emergence is best understood as a contextual phenomenon.

2. Overview of papers in volume 2

In 'Manipulationism and Causal Exclusion', Mark Pexton examines causation itself as an emergent feature of the world. Pexton examines the notorious causal exclusion argument, associated with the work of Jaegwon Kim (e.g. Kim 1999) from within one particular framework of causation—manipulationism. In manipulationism, causal explanations are defined by counterfactual information accessed through manipulations. It is argued that the property of manipulability can be an emergent property of aggregate systems. Therefore, some causal explanations are non-reducible and causal exclusion is avoided.

Building on this, it is then argued that it is possible for aggregate systems to produce collective properties which ground the causal relation, whereas those same systems described in terms of fundamental relations alone, cannot be described properly as causal. If this is correct, then, at least in some cases, a particular physical system being a *causal* system will itself be a matter of emergence. The example of white dwarf stellar physics is discussed in detail in order to illuminate and motivate this central claim.

In 'Quantum Mechanics, Emergence and Fundamentality', Peter Lewis explores whether or not quantum mechanical phenomena, especially the behaviour of entangled particles, provide good evidence of the existence of strongly emergent entities. Whilst it might be thought that the quantum world provides the emergentist with powerful examples of putatively strongly emergent phenomena, how to properly interpret quantum mechanics is a highly contentious matter, and so one has to be cautious when attempting to make use of the results of quantum mechanics in order to secure metaphysical conclusions.

Lewis carefully formulates the standard argument for strong emergence based on quantum mechanics, then addresses two potential objections to the claim that quantum mechanics supports emergentism.

The first of these is that the argument makes use of Bell's theorem, but Bell's theorem itself is contentious, and the premises supporting it are often rejected. The second objection centres around the conceptions of part and whole that proponents of the argument assume. Each of these objections can be met, and so Lewis concludes that quantum mechanics does support emergentism—an indirect argument which avoids the abovementioned objections can be run which aims to show that emergent properties represent an ineliminable part of the explanation of measurement outcomes for entangled systems according to all of the best developed interpretations of quantum mechanics.

In 'Topological Order and Emergence', Jonathan Bain offers a critical assessment of the claim that systems that exhibit topological ordering—for instance topological insulators, topological superconductors and systems which produce the quantum Hall effect—support emergentism. The paper distinguishes between two kinds of topological order: the first is *symmetry protected topological order*, which is underwritten by mechanisms involving short-range entanglement; the second is *intrinsic topological order*, underwritten by mechanisms involving long-range entanglement.

However, Bain argues that despite these differences, the two types of topological order can be unified, as, at least with regard to their behaviour in certain energy regimes, both sorts of system can be described using effective topological quantum field theories. Bain builds on this observation to argue that, insofar as these examples support the existence of emergent phenomena, that phenomena ought to be primarily conceived of in nomic terms, rather than in mechanism-centred termed. That is to say, what is novel about the emergent features of these systems is that they come to be characterised by novel, distinct laws.

In 'Strong Emergence and Downward Causation in Biological Physics', Tom McCleish examines a number of potential examples of phenomena exhibiting downward causal influence from the realm of the biological—

including protein assembly; gene expressions and the topological interaction of DNA and topoisomerase enzymes. McLeish conceives of downward causation in the following terms: a system exhibits downward causal influence if the future behaviour of that system as a whole is not fully determined by the low-level entities that make up that and their interactions. He argues that information flow ought to be taken as a indicator of emergence: when a system is such that it carries information at larger scales (high-level information) which is not fully constituted by the sum of information available at smaller scales (low-level information), then that system should be considered to exhibit strong emergence.

The introduction of these biological case studies into the debate is particularly valuable, McLeish claims, as they offer a context in which to discuss the issue of downward causation other that of the relationship between the mind and body—itself a particularly fraught and thorny area of enquiry. These examples thus have the potential to shed new light on questions concerning, for example, causal exclusion and the completeness of physics.

In the final paper of the volume, 'Emergence, Causation and Storytelling: Condensed Matter Physics and the Limitations of the Human Mind', Stephen Blundell examines the relationship between the physics of systems with vast numbers of constituent parts; the inherent cognitive limitations of human beings as investigators of such systems and explanations which make recourse to concepts such as emergence. Drawing on a number of examples from within both condensed matter physics and the study of cellular automata, Blundell argues that emergent narratives are a necessary, justified and felicitous way of describing phenomena which, in their totality, are beyond our comprehension.

Framing the question of emergence in these sorts of terms might initially seem to render it an epistemic matter. Whilst Blundell takes there to be an unavoidable epistemic dimension to questions concerning

emergence and reduction, he urges that the relevant features of the sorts of systems under discussion in this paper have genuine ontic status—to dismiss them as *merely* epistemic would be to miss the point.

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ACKOWLEDGEMENTS

This publication was made possible through the support of a grant from the John Templeton Foundation. The opinions expressed in this publication are those of the author(s) and do not necessarily reflect the views of the John Templeton Foundation. The editors also extend their thanks to all the contributors; to the editorial board of *Philosophica* for their help and support during the production of this special issue and to Professor's Robin Hendry and Tom McCleish and the rest of the *Durham Emergence Project* team—the editors all worked as postdoctoral researchers on this project and it was during that time that this special issue was conceived.

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