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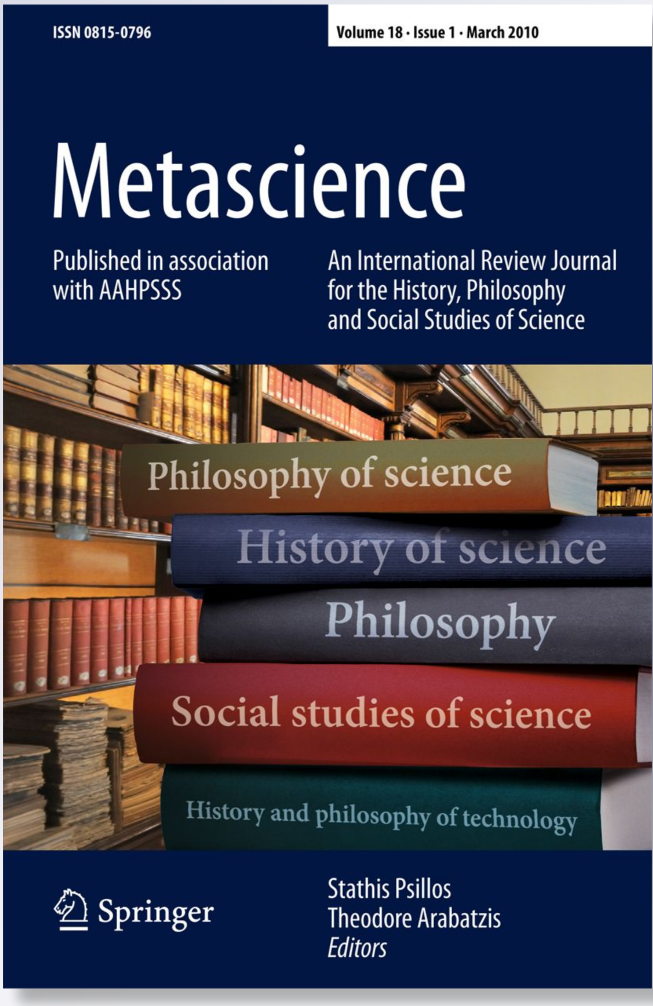

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SURVEY REVIEW

Emergence and reduction in context: Philosophy of science and/or analytic metaphysics

Jakob Hohwy and Jesper Kallestrup (eds): Being reduced: New essays on reduction, explanation, and causation. Oxford: Oxford University Press, 2008, 312pp, $99.00 HB

Mark A. Bedau and Paul Humphreys (eds): Emergence: Contemporary readings in philosophy and science. Cambridge, MA: The MIT Press, 2008, 464pp, $85.00 HB

Antonella Corradini and Timothy O'Connor (eds): Emergence in science and philosophy. London and NewYork: Routledge Studies in the Philosophy of Science, 2010, 314pp, $128.00 HB

Michael Silberstein

Introduction

The sociology and psychology of emergence-talk in the sciences and in philosophy has always been complex to say the least. Perhaps the right word for people's reaction to the topic of emergence (if it is a well-defined topic) is bi-modal. Of course, this is much less true of the topic of reductionism. For example, people (philosophers especially) often bristle at even the mention of the word 'emergence' claiming it is too multifaceted, vague or ambiguous to be coherent. However, one never hears that about the word 'reduction', the use of which is equally ubiquitous and equally heterogeneous. This is ironic given that for the vast majority of working scientists in every field who speak of emergent phenomena, such talk does not constitute a rejection of the idea that explanation is ultimately reductionist in *some sense*. It is also ironic given the anti-reductionist and anti-monistic spirit in philosophy of science at the moment.

The cheerleading take on emergence-talk tells us that it has been an important topic in Western philosophy on and off at least since Galen or Aristotle. Thanks to factors such as: (1) its resurrection across the sciences of and foundations of 'complexity' (another loaded word) that range from Condensed Matter Physics to network theory and (2) renewed philosophical interest in consciousness and its bearing on the physicalism debate of analytic metaphysics; the topic of emergence

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is now one of the most important and ubiquitous in both science and philosophy. Those who champion emergence as a sweeping academic movement spanning several disciplines often point out that some of the key unifying factors are a failure of certain reductionist methods both mathematical and mechanistic, a convergence upon formal explanatory tools from dynamical systems theory, network theory, Renormalization Group Theory and a general focus on large-scale systemic behavior, such as topological, graphical and dynamical features. Ever since P. W. Anderson's landmark paper 'More Is Different: Broken Symmetry and the Nature of the Hierarchical Structure of Science' in 1972 (Bedau and Humphreys, Chapter 10), schemes for an emergence or complexity Theory of Everything have often been based on spontaneous symmetry breaking, universality and phase transitions. However, many writers, both friend and foe, equally stress the pluralistic nature of emergence-talk.

The naysayers of emergence-talk claim that while syntactically the same word is being used across a number of different disciplines and sub-disciplines, the use of the word is highly disunified, its various referents and connotations absurdly heterogeneous. They also claim that the use of the word is often vague and nebulous, making it practically incoherent for some. For example, skeptics like to point out that there really is no such thing as a *discipline* of emergence. Furthermore, even within single disciplines such as philosophy, the term is used in very different ways, signifying very different projects. In analytic metaphysics (of which philosophy of mind is a subset), various doctrines of emergence are cooked up as general metaphysical 'isms' on a par with, and sometimes in competition with, physicalism. While in philosophy of science, specific possible cases of emergence are individually analyzed across a variety of different scientific disciplines. These scientific case studies of course represent very different uses of the term. One good example of the slipperiness of the terms 'emergence' and 'reduction', as noted by Butterfield and Isham (1999, 112), is the fact that when physicists says things like time or spacetime is 'emergent' from a more fundamental (possibly discrete) theory than general relativity or even quantum mechanics, they mean time could in some sense be derived from, that is, *reduced to*, the more fundamental theory in question.

At the very least, we can say that analytic metaphysics is more concerned with the *ontological* possibility of emergence *in principle* and philosophy of science with emergence in *practice*—actual scientific *explanation*. In any case, skeptics would be the first to point out that across the three volumes being reviewed here, the topics range from: the emergence of classical physics from quantum physics, asymptotic singular limits within classical physics (emergence as classical phase transitions), emergence of life from chemistry, emergence of embodied cognition, emergence of group cognition, emergence of consciousness, to the emergence of souls! So the question is 'What beyond academic trendiness and multiple uses of the word 'emergence' justifies an edited volume that spans such radically diverse subjects?

But again, it must be said, the same admonishment is never given for the use of the term 'reduction', even though many forms of reduction are compatible with many forms of emergence. The preface of the edited collection *Being Reduced: New Essays on Reduction, Explanation, and Causation* says when it comes to reductionism writ large, 'there are few more unsettling [and important] philosophical questions than this' and 'Reduction can easily seem to unravel our world'. Of course, if this is true, then it is equally true of the concerns of emergence, even if only to show that some particular type of emergence does not conflict with reductionism of some particular type.

The truth about emergence-talk is in the middle, somewhere between the cheerleader and the skeptic. Therefore, it should come as no surprise that both the champions and the skeptics of emergence-talk have cogent points and that the discussions of emergence and reduction must often (but not always) go hand in hand. The review of these three edited volumes will go as follows. First, a general framework and taxonomy pertaining to different types of emergence and reduction will be introduced. Second, using that taxonomy, each volume will be characterized individually, but also comparing and contrasting each along the way. Third, the volumes taken as a set will be used to say something about the current state of the emergence/reduction debate. Finally, suggestions and hopes will be articulated for the future direction of the debate.

Taxonomy

Some general remarks are in order. First, almost every chapter in these volumes has its own taxonomy and terminology related to emergence or reduction. Sometimes different authors even use the same expression such as 'strong emergence' to mean different things. Trying to map all these varying taxonomies onto one another would be an exercise in futility; therefore, my own (admittedly incomplete) taxonomy will be extended and the other taxonomies subsumed under it (Silberstein 2002, 2009). Second, the claim that X is emergent is usually made relative to some presumably more fundamental phenomenon, theory, behavior, etc., upon which X depends in some sense and has autonomy from in some sense. The specific sense of dependence and autonomy in question must be determined on a case-by-case basis. The idea here is that the emergent phenomenon, theory, behavior, etc., in question is *in some sense* less fundamental than its base and *in some sense* not reducible to its base. The idea that emergent phenomena are neither fundamental (axiomatic) nor reducible/derivable (a theorem) leads many to call into question the very coherence of the idea of emergence. But a phenomenon can simultaneously be both fundamental and emergent in *many different senses*, so long as the set of claims does not entail a contradiction of course.

However, third, often proponents want the alleged emergent phenomena to be explicable, but fail to be reduced in *some* sense of that word, hence the term emergent. For most scientists and philosophers, it is fair to say that explanation is by definition reductionist in some sense of the word. Therefore, a great deal of skepticism is generated regarding any claim to emergent phenomena that are supposedly thoroughly explained, but not in *any* reductionist sense of explanation. The defender of emergence must somehow convince people that: (1) the phenomena in question is not just another brute/fundamental fact in some key sense, (2) that it cannot in principle be explained reductively in some key sense, and (3) that it has a truly explanatory non-reductive explanation in some key sense.

Fourth, it must also be noted that X could be co-emergent from Y and vice versa, without either being more fundamental than the other in some absolute sense. Indeed, it is possible that there are no fundamental entities in any absolute sense. For example, if wholism were true, the idea that the whole is fundamental (e.g., the universe) and the behavior of the parts is determined contextually only by their role in the whole, that would certainly nonetheless imply some kind of emergence. There are in fact monistic accounts of emergence and pluralistic accounts, and some are both in certain respects.

Here is a list of basic questions to check off whenever claims about emergence or reduction are made:

(1) How is the term 'emergence' or 'reduction' being used? In the case of reduction are we talking about some type of intertheoretic reduction, mechanistic reduction or something else such as functional reduction? If the former type of reduction, then what is the conception of intertheoretic reduction being employed, e.g., the D-N Model or a more mathematical one such as smooth asymptotic relations. If mechanistic reduction, then what are the conditions for successful mechanistic reduction, e.g., what is the specific account of localization and decomposition on offer. In the case of emergence, are we talking about some form of novelty in terms of some specific kind of irreducibility, unpredictability, unexpectedness, etc. In other words, the specific autonomy and dependence relations in question should be articulated. Furthermore, is the form of emergence in question purely ontological, epistemic/explanatory or something that straddles both categories? Whether emergence or reduction is at issue, in answering these questions it should be clear exactly what sort of *explanation* is being offered. We need to be concerned not only with how the target phenomenon is being explained (or fails to be explained), but what it in turn allegedly explains.

(2) What is the type of thing being reduced or alleged to emerge? Examples include: properties, entities/things, behavior, mechanisms, laws, theories, models, processes, levels, causal powers, substances, agents, patterns, etc.

(3) Is the kind of emergence or reduction in question diachronic/dynamical, synchronic or both? There are at least two possible meanings of the claim that a phenomena P is diachronically or dynamically emergent, and they are quite different. The first is that P has causal powers, capacities, etc., neither synchronically nor diachronically determined by the base or lower-level causal processes. The second is that P only emerges as, at least in part, a function of some dynamical lower-level or more basic process that unfolds in time. As the system evolves in time new 'higher-level' properties will come into being as a function of the unfolding of the more fundamental dynamical process. The first kind of dynamical emergence is a kind of ontological causal emergence and the second kind is typically called "weak emergence" (see below for more details).

(4) Is the emergent phenomena in question only emergent relative to an observer, class of observers, models, etc., (observer dependent emergence), or is the emergent phenomena emergent absolutely and universally, with or without the relevant observers, models, etc., (absolute emergence).

What follows is the taxonomy itself. It is profitable to divide claims to emergence and reduction into those that involve *ontological determination relations* and those that involve *explanatory relations* broadly construed to include: prediction, derivability, conceptual novelty, etc.

Regarding ontological determination relations, we can divide them into logical, nomological, causal, mereological and natural kind (or types) relations. First issue, Does the phenomena P in question logically (or 'metaphysically') supervene on the more fundamental phenomena Q in question? P is logically/metaphysically supervenient on Q if and only if there is no possible world in which an object could have had Q, but lacked P. For example, Chalmers has famously argued that conscious experience (and only conscious experience) is *logically emergent* with respect to physical phenomena (Bedau and Humphreys, Chapter 23). Notice that phenomena P can fail to supervene on Q with logical necessity but still supervene with brute nomological necessity. This is in fact Chalmers' position regarding conscious experience, that is, he posits universal brute psycho-physical bridge laws that determine the distribution of conscious properties given physical properties (ibid). Another iconic example of *logical emergence* is C D Broad's non-universal compositional laws, that is, brute physical–chemical bridge laws that only come into play when certain specific chemical compounds/molecules interact (McLaughlin in Bedau and Humphreys, Chapter 1). Let us be clear that emergent laws need not be first-order dynamical laws such as Newton's laws of motion, they could be invariances, symmetries, constraints and regularities of all sorts. Indeed, such emergent or novel laws could be the result of symmetry breaking, asymptotic singularities, phase transitions, etc. Whether emergent laws must be *brute* in order to count as ontologically emergent is a matter of some debate (P. W. Anderson in Bedau and Humphreys, Chapter 10).

Secondly, phenomena P could fail to either logically or nomologically supervene on its base phenomena. In such a case, the base phenomena would provide only a necessary condition for the emergence of said phenomena; other essential conditions would include those beyond the base. Bishop (2010) calls this kind of emergence '*contextual emergence*'. He (2010, 5) argues, for example, that quantum phenomena provide only a necessary condition for the emergence of molecular structure. The necessary and sufficient conditions for the emergence of molecular structure with classical observables will include several classical contextual features in addition to the quantum features. Notice that in this case, there is no absolute sense in which the quantum is more fundamental than the classical.

Third, phenomena P might be *causally emergent* with respect to Q. In the parlance of analytic metaphysics, P has 'causal powers' that depend on the causal powers of Q, but they will not simply be identical to them. One need not buy into the arcana of causal powers to believe in causal emergence. The claim that mental processes exhibit 'downward' causation with respect to neurochemical processes is a strong form of causal emergence.

Fourth, phenomena P might both logically and nomologically supervene on Q, but fail to mereologically supervene on Q. A *mereologically emergent* property is a property predicated of the whole that is not mereologically determined at a time t by the properties and relations predicated of its proper parts. In the parlance of analytic metaphysics, compound entities (wholes) are 'composed' of their proper components, and the properties of the components 'realize' (synchronically or non-causally determine) the properties of the compound (Gillett in Corradini and O'Connor, Chapter 2). Mereological emergence would be a violation of such composition and realization relations (Silberstein 1999; 2009 and forthcoming). In other words, mereological emergence is a violation of what Weinberg calls 'constituent reductionism' (Weinberg in Bedau and Humphreys, Chapter 18). Such emergence is also a violation of what Lewis calls 'Humean supervenience' and Kim calls 'mereological supervenience' (Silberstein 1999 and forthcoming). Many of us have argued that quantum entanglement provides an example of mereological emergence (Hawthorne and Silberstein 1995; Silberstein 1999; 2002; 2009 and forthcoming). Mereological emergence need not be as esoteric as quantum entanglement. For example, with regard to mechanistic explanation in complex biological systems, a principled failure of localization and decomposition for whatever reason could constitute another kind of mereological emergence (Chemero and Silberstein 2008; Silberstein and Chemero 2011). A failure of localization and decomposition in a complex biological system could also constitute a kind of causal, dynamical or diachronic emergence in one sense or another (ibid). (For the best discussions of mechanistic reduction among these volumes see Chapters 1–3 and Chapter 12 of Hohwy and Kallestrup. See also Chapter 5 of Corradini and O'Connor).

Finally, phenomena P might be *type emergent* in which they constitute metaphysically irreducible natural kinds. This would be a natural kind in the higher-level theory that cannot in principle be eliminated or identified with a natural kind in the reducing theory. The natural kind in question could be something relatively humble such as a new kind of behavior, property, etc., or it could be something grand like life, intelligence or conscious experience.

Moving away from overtly ontological notions of emergence and reduction, there are explanatory relations. Here are two such versions of emergence, the first kind stronger than the second. Certain wholes (systems) appear to have features that cannot *in practice* be derived, explained or predicted from the features of their parts; their mode of combination and the laws governing their behavior even though the features of the whole may be logical consequences of the features of the parts. We can say that in such cases X bears *predictive/explanatory emergence* with respect to Y. In analytic philosophy of mind, McGinn and other so-called 'mysterians' famously hold that conscious experience is emergent in this sense with respect to neuroscience even though the identity theory may well be true. Notice that in this case, neuroscience cannot even explain why it cannot predict, derive or otherwise explain conscious experience; which of course raises the question of how we could then ever come to be justified in believing the identity theory is true. In philosophy of science, a notable form of predictive/explanatory emergence is what Mark Bedau calls 'weak emergence', according to which features of a macroscopic state can be derived from a knowledge of the system's microdynamics and external conditions, but *only* by simulating it—that is, by modeling *all* the interactions of the realizing microstates leading up to it from its initial conditions (Bedau in Corradini and O'Connor, Chapter 3; and also Bedau and Humphreys, Chapter 8). Weak emergence, therefore, equals 'explanatory incompressibility'. Such behavior is underivable except by dynamical/diachronic simulation, such as A-Life or finite automata in general. There are different degrees and types of weak emergence to be sure, but in all cases, ontological microdetermination always holds, again raising the question how one knows that to be true under the circumstances. This kind of emergence is sometimes called computational irreducibility, and there are various measures of computational complexity that allow one to characterize the different strengths and types of computational irreducibility (Bedau and Humphreys, Chapters 15–17).

A second form of explanatory emergence concerns the representational resources needed to represent phenomena. Certain wholes (systems) exhibit features, patterns, behaviors or regularities that cannot be fully represented and understood using the theoretical and representational resources adequate for describing and understanding the features and regularities of their parts and reducible relations. Even when the properties of the whole are metaphysically or otherwise determined by the properties of the proper parts of the whole, we might not be able to model the properties of the whole in terms of the vocabulary that we use to model the properties of the parts. According to many, for example, this is precisely the situation that confronts us in attempting to understand conscious experience and intentionality: conscious and intentional events themselves are 'nothing but' neurophysiological events, but we cannot accurately model them with the descriptive resources of the vocabulary of neuroscience alone. Instead, many claim that we must appeal to folk psychology and phenomenology in order to *understand* conscious experience and intentional action. X bears *representational/cognitive emergence* with respect to Y, if X does *not* bear predictive/explanatory emergence with respect to Y, but nonetheless X represents higher-level patterns or regularities that cannot be fully, properly or easily represented or understood from the perspective of Y. That is, in such cases, there need be no great inexplicable failure of prediction or derivability in practice, but nonetheless, for reasons perfectly understood by all, X has great explanatory advantages over Y. Many non-reductive physicalists take this view about both folk and scientific psychology with respect to neuroscience. They hold that even if one could derive conscious experience or folk psychology from neuroscience, one would still lack the powerful *understanding* of conscious intentional processes and their relation to behavior that the former provides.

Whether a particular case is an instance of predictive/explanatory emergence or merely representational/cognitive emergence may not always be clear. For example, people might disagree about various specific idealizations or approximations. Indeed, people may even disagree about whether a case of emergence is ontological or merely explanatory. For example, how do you know when a natural kind is only explanatorily emergent or truly ontologically emergent? Such a claim is vague or even fuzzy with respect to the ontology versus explanation distinction, and can thus be spun either way. The distinction between ontological emergence and explanatory emergence presupposes a hard and fast dichotomy between ontology and epistemology, but in some cases, this distinction becomes even fuzzier than what we have seen thus far. Bedau calls some cases of this sort 'in-principle irreducibility in practice' (Bedau in Corradini and O'Connor, Chapter 3). Computational irreducibility of one sort or another has often been given as an example of a kind of emergence that straddles both epistemology and ontology. Perhaps the most well-known case of this is the sensitivity to initial conditions exhibited by chaotic systems. If a system exhibits sensitive dependence to initial conditions, any measurement uncertainty will be amplified (exponential amplification of errors), such that infinite computational power (an infinite amount of information stored in the computer) would be required to predict the evolution of the system. Needless to say, this is *physically* impossible (Cruchfield, Farmer, Packard and Shaw in Bedau and Humphreys, Chapter 20). Laughlin and Pines argue that attempting to derive molecular structure from the Schrödinger equation, which should be possible in principle, would also require infinite computational power because if the amount of computer memory necessary to represent the quantum wavefunction of one particle is N, then the memory required to represent the wavefunction of k particles is N^{k} (Bedau and Humphreys, Chapter 14). There are many other such examples in the literature on computational irreducibility.

Comparing volumes

What all three of these edited volumes on emergence and reduction have in common is an eclectic combination of chapters from analytic metaphysicians and philosophers of science. Two of these volumes, Bedau and Humphreys and Corradini and O'Connor, provide excellent introductions, overviews and framing text that go well beyond a mere summary of the chapters. Only the Bedau and Humphreys volume has any serious representation from actual scientists, though most of those articles are classics of emergence and complexity theory such as chapters by Herbert Simon, P. W. Anderson, Steven Weinberg, Robert Laughlin and David Pines, James Cruchfield, Stephen Wolfram, etc. All of the chapters in Bedau and Humphreys have been published before. The chapters by non-scientists are likewise classic papers on emergence and reduction in analytic metaphysics and philosophy of science by the likes of Jerry Fodor, Jaegwon Kim, Daniel Dennett, Paul Humphreys, William C. Wimsatt, David Chalmers, Ernest Nagel, etc. In order of emphasis on philosophy of science over analytic metaphysics, the volumes rank as follows: Bedau and Humphreys, Hohwy and Kallestrup and Corradini and O'Connor. The latter volume has the greatest number of chapters on standard issues in analytic philosophy of mind such as mental causation, free will and the hard problem of consciousness. It is also the only volume to include chapters on emergence with regard to the hierarchy of formal systems such as the Galvan chapter on omega-incompleteness, which focuses on the relationship between truth and derivability (Corradini and O'Connor, Chapter 12). Bedau and Humphreys has the greatest number of chapters on computational irreducibility, while Hohwy and Kallestrup have no chapters on that topic whatsoever. The latter has the greatest emphasis on emergence and reduction within cognitive science, neuroscience and biology, for example, mechanistic reduction and its limits. Ironically, perhaps, it is also the volume with the greatest emphasis on straight up analytic metaphysics, with chapters on physicalism, the exclusion problem, determinable properties, causation and laws.

In summary, in terms of overall thematic coherence, the Bedau and Humphreys volume is the tightest. This volume succeeds at bringing together foundational articles in analytic metaphysics, philosophy of science and science, all connected by illuminating framing text. Hohwy and Kallestrup is the runner up in this regard, but just barely given the mix of philosophy of cognitive science, neuroscience and biology with pure analytic metaphysics. The Corradini and O'Connor volume, though it has excellent introductions for each section, feels the most like an edited conference volume, and it is the most heterogeneous topically.

The current state of play

Suppose that we take these volumes as artifacts of the current zeitgeist of the emergence/reduction debate and ask ourselves what they tell us about the state of play. As remarked earlier, perhaps the most general division in the literature on emergence and reduction is that between analytic metaphysics and philosophy of science, excluding science itself of course. Even this distinction is tricky and probably more of a continuum than a dichotomy. For example, Humphreys' seminal 1997 article 'How Properties Emergence' (Bedau and Humphreys, Chapter 6) that first appeared in *Philosophy of Science* is beloved by many of us and often considered the philosophy of science of emergence par excellence. However, the paper is largely motivated by and a reaction to Kim's exclusion argument and downward causation argument. The 'fusion' account of property emergence that Humphreys provides is a perfectly general and 'abstract' metaphysical account. He is providing a proof in principle that there is an account of property emergence that is coherent in that it avoids the problems raised by Kim's arguments. On these grounds, Humphreys claims such an account would be useful even if there were no real world instances of fusion. He does suggest, though, that quantum entanglement might be such an instance (Bedau and Humphreys, 122). However, in response, many of us have argued over the years that the fusion account is too strong even for quantum entanglement, and it is certainly too strong for emergence in classical systems (Kronz and Tiehen 2002; Wong 2006; Silberstein forthcoming). So is Humphreys doing analytic metaphysics, philosophy of science or both? Gillett's chapter on emergence and reduction in Corradini and O'Connor claim to be doing 'metaphysics of science', a movement within analytic metaphysics devoted to the 'abstract examination of ontological issues as they arise in science and real scientific cases' (Chapters 3, 26). While the chapter does talk some about mechanistic reduction in neuroscience, most of the chapter is devoted to accounts of 'realization' and their metaphysical implications for the possibility of emergence. Gillett is also primarily interested in providing abstract and general accounts of realization and emergence. So even if we say that Humphreys and Gillett are doing, at least in part, philosophy of science, we need a more fine-grained distinction.

Another approach to emergence and reduction within philosophy of science is to begin with some detailed exegesis of some first-order scientific case such as: quantum entanglement, the emergence of the classical from the quantum, phase transitions, symmetry breaking, asymptotic singularities, computational irreducibility, nonlinearity of various sorts such as chaos, protein folding, epigenomics, neural plasticity, memory consolidation, extended cognition, (Chemero and Silberstein 2008; Silberstein and Chemero 2011) etc. Having provided the gory empirical details, one then goes on to discuss what sort of reduction and/or emergence might be being exemplified. This 'science-first approach' (Silberstein 2011a, b) to emergence and reduction holds that metaphysics should be subsumed under first-order philosophy of science as much as possible, for example, philosophy of physics, biology, cognitive science, neuroscience, etc. Unlike some other approaches of this sort (e.g., Ladyman and Ross 2007), this approach does not entail the anti-metaphysical spirit tout court of the logical positivists, does not shrink from the necessity of conceptual analysis and does not entail that physics is unconditionally more special or fundamental than the 'special' sciences. This approach does, however, require that practitioners start with the scientific details and be well-versed in their particular science.

Within this science-first approach, even more distinctions need to be made. This is nicely illustrated by Bickle's chapter in Hohwy and Kallestrup entitled, 'Real Reduction in Real Neuroscience: Metascience, Not Philosophy of Science (and Certainly Not Metaphysics!)'. This is certainly an instance of the science-first approach. Bickle argues that analytic philosophy is infected by armchair metaphysics and normative epistemology, and that much of philosophy of science is, in turn, still infected with analytic metaphysics. He points out, for example, that neither the D-N model nor the functional reduction of people like Kim is anywhere to be found in science, let alone neuroscience. Bickle says we should let science tell us what reductionism is. He says if you follow that rule you discover in neuroscience that for many cognitive functions, the best causal-mechanical explanation now resides at the molecular and cellular level. To claim, otherwise he says, is not 'neurobiologically plausible' (50).

This 'ruthless reductionism' immediately runs into a problem: There are many other areas of neuroscience such as network neuroscience, social neuroscience, etc., where the best explanations are not currently molecular and cellular, nor are they likely to ever be given their explanatory focus. Hardcastle and Stewart's chapter in the same volume as Bickle argues that much evidence from medicine and psychiatry suggests that many explanations for human cognition, behavior, disorders, etc., will be essentially embodied and even extended. In their own words, neuroscience and philosophers, thereof, have an unjustified bias toward 'smallism' when it comes to explanation. The fact is, neuroscience and science, in general, are much more pluralistic than Bickle allows. Therefore, we cannot simply turn over all authority to scientists in these matters.

Leaving aside the question of how to qualify the science-first approach for a moment, the main point here is that if these three volumes are representative, this approach is still in the minority among philosophers working on emergence and reduction today. There are certainly some exceptions in these volumes of course. However, if these volumes, all edited by philosophers mind you, are any indicator, the philosophical community writing on emergence and reduction thinks that progress will best be made by cross-talk between a bewildering variety of analytic metaphysicians and philosophers of science, but not necessarily those practicing the science-first method. Regarding scientists themselves, except for the aforementioned classic papers in Bedau and Humphreys, they are largely missing from the stage. This is all somewhat ironic because science-first is definitely the trend within philosophy of science proper (Machamer 2002).

The future direction of the debate

To make progress, it is essential that philosophers fully embrace the need for explanatory and ontological pluralism when it comes to reduction and emergence. Different cases require different conceptions of emergence. It is absurd for philosophers to try and argue that any particular conception of emergence is inherently superior across the board. To engage in such a battle of 'isms' is just to turn what ought to be empirically driven discussions into pure analytic metaphysics. Fortunately, some of the authors in these volumes explicitly recognize the need for pluralism. While we are on the subject of pluralism, it is worth noting that the topic has become important in its own right in philosophy of science. The point is raised because while it is often thought of as distinct from the emergence/reduction debate, the pluralism/monism debate as it is called, is very much a subset or dimension of the former debate. The emergence/reduction discussion and the pluralism/monism discussion would both be enriched by becoming more integrated (see Silberstein 2011a and b for more detail).

What is important for our purposes, however, is while the kind of pluralism being advocated for in this review is certainly a brand of the science-first approach, it does not blindly cede final authority to science nor is it unqualifiedly anti-metaphysical. Note the irony that both the 'ruthless reductionism' of Bickle, a kind of super-monism, and the anti-monistic pluralists like Kellert (2006), both call for an end to metaphysics and both push science as the final authority, yet they draw utterly opposing conclusions about what science is telling us. The science-first approach, however, properly conceived need not beg the question for or against any specific kind of reduction/monism or emergence/pluralism in any particular case study. It will take on board the pluralistic nature of scientific discourse, and it will acknowledge that there will often be plenty of disagreement even among experts about what a particular case study entails with respect to reduction and emergence. It is in part the job of philosophers of science to challenge the methodological and metaphysical assumptions of science and subject their inferences to greater scrutiny. Science as a tool for doing metaphysics is certainly limited, but it is the only game in town if both ontological and methodological naturalism are to be taken seriously. Another problem with certain types of radical pluralism is the operational skepticism about unification or seeking integration in the sciences. But neither the science-first approach nor the acceptance of explanatory pluralism rules out the possibility of some types of unity and integration, both within and across the sciences.

This brings us to the topic of analytic metaphysics and its proper role in the emergence/reduction debates. The kind of science-first account being expounded in this review is not hostile to ontological claims and pursuits as such, indeed, they can hardly be avoided in science or by science. It is just that such pursuits should begin from within science and carried out in a science-first fashion. But this account does suggest that there is no need for, say, philosophy of mind qua analytic metaphysics, in addition to philosophy of psychology, cognitive science and neuroscience. It also suggests that purely armchair accounts of supervenience, realization, emergence, reduction, etc., are not likely to be helpful. Therefore, it would be nice to see more edited volumes on emergence and reduction that are filled with actual practicing scientists engaging with science-first philosophers of science.

There are some chapters in these edited volumes that can be used as foils to illustrate the differences between the science-first way and that of analytic metaphysics. The first is the Gillett chapter mentioned earlier. In this chapter, he argues that 'mechanistic' explanation is a prevalent type of ontological reductionism in science, best characterized in terms of the composition of higher-level entities by their lower-level parts and the realization of higher-level properties of the wholes by the lower-level properties of the parts, both non-causal synchronic determination relations (Corradini and O'Connor, 29–31). He is adamant throughout that there are no exceptions in science to this mereological ontology. He also seems to think that any exception would constitute a rejection of physicalism. However, as many of us who practice science-first philosophy of science have been pointing out over the years, quantum entanglement provides such an exception (Hawthorne and Silberstein 1995; Silberstein 1999, 2002, 2009 and forthcoming); Maudlin 2007; Butterfield 2010). Entangled states are not *composed* of the particles that enter into them, and the properties of entangled states are not *realized* by the properties of the particles that enter into them. This is evidenced time and time again by both the formalism of quantum mechanics and a myriad of experiments.

To this day, the defense given by those who nonetheless continue to champion compositional and realizationist accounts of reduction is pretty much the same as that given by analytic metaphysicians Lewis and Kim decades ago; the former in defense of his 'Humean supervenience' and the latter in defense of his 'mereological supervenience' (Silberstein 1999 and forthcoming). Namely, quantum mechanics is too immature a science and too poorly understood to base ontological inferences on. From the perspective of science-first philosophy of science, this is a jaw-dropper. While many of the interpretational issues of quantum mechanics are not resolved, virtually everyone in the know agrees that quantum entanglement is most definitely a violation of composition and realization. They would also point out that quantum mechanics is the most highly predictive theory in existence and has never been in any way falsified or impugned experimentally. For a physicalist, to push skepticism about quantum mechanics, its success being perhaps the best reason to believe in physicalism in the first place, is a sure sign that something is rotten in Denmark.

Another common defense is to argue that even if composition and realization fail within microphysics that does not entail that they fail universally all the way up the chain (Papineau in Hohwy and Kallestrup, Chapter 7). So, for example, even though they fail for entangled states in quantum mechanics, it could still be true that molecules compose neurons and the properties of the former realize the properties of the latter. Papineau argues that physicalism (P: all facts metaphysically supervene on the physical facts) could be true even though microphysicalism (M: all physical facts metaphysically supervene on the microphysical facts) is false. He does not provide any detailed reasons as to why one might doubt M, but he does mention 'quantum holism' as a possible worry. Here we need to be careful to distinguish between mereological supervenience and logical/metaphysical supervenience. If Papineau is merely claiming that quantum entanglement (a failure of composition and realization—a failure of *mereological supervenience*) is compatible with P, he is of course correct; a fact that Gillett does not seem to appreciate. Indeed, part of the point here is that both P and M are compatible with even the *universal* failure of composition and realization. P is, for example, compatible with universal quantum entanglement, entanglement that exists at macroscopic length scales that is masked by environmental decoherence. Composition and realization relations are just one ontological possibility, among many, for the implementation of physicalism. In addition to quantum entanglement, for example, there are specific interpretations of quantum mechanics that entail the universal failure of both composition and realization. Interpretations of quantum mechanics aside, the standard environmental decoherence explanation for why large 'macroscopic' quantum systems behave (for all practical purposes) classically is not consistent with composition or realization (Silberstein, forthcoming). But all of this aside, if composition and realization fail in fundamental physics, then *why* should we believe they are nonetheless the correct account further up the ladder.

On the other hand, if Papineau is in fact actually claiming that P could be true even though physical facts fail to *logically supervene* on microphysical facts, this is another matter. He is right that P and M are logically distinct claims. He is also right as a matter of logic that there could be only 'Broad-Laws' connecting microphysics with chemistry, but that all higher-level facts nonetheless logically supervene on chemical facts. But surely, if one is somehow justified in believing that chemical facts do not logically supervene on microphysical facts, then one has every reason to believe that still higher-level facts probably do not (or need not) logically supervene on chemical facts in turn. Again, it is precisely the explanatory success of microphysics across the board that is the best reason to believe in P in the first place. Papineau's reply is that in fact the best reason to believe in P is not the explanatory success of microphysics, but the causal completeness of physics (CoP). First, the obvious problem with this reply is that CoP does not entail physicalism defined as P. For example, CoP is consistent with the existence of supernatural souls so long as they remain epiphenomenal. Second, this reply just begs the question as to why one should believe in CoP. And again, the claim would be that the best evidence for CoP must surely come from fundamental physics, where else. That is to say, surely we are more justified in the claim that microphysics does not ever require mental 'forces' than the claim that neural systems or human behavior never require mental 'forces' to explain their evolution. Surely the relationship between neural facts and mental facts is much more puzzling, much more likely to elicit a view like C D Broad or Chalmers, than the relationship between microphysical and chemical facts. Both microphysics and macrophysics are more successful explanatorily (or at least predictively) than any special science to date. The beauty of physicalism, for those who believe it, is its unifying power wherein all of reality is determined by fundamental microphysical facts (initial and boundary conditions) and laws. Thus, 'Broad-Laws' of any sort, but especially within fundamental physics itself, would be a blight on this beauty, calling the whole story into question. This is why physicalists often invoke finite automata such as the Game of Life, as a model or metaphor for physicalism (Dennett in Bedau and Humphreys, Chapter 9).

Quantum mechanics trumps composition and realization. Indeed, if one started with quantum mechanics rather than abstract armchair analytic theorizing, one would never have cooked up composition and realization relations to begin with. At the very least, we have seen that such relations cannot be the basis for any *universal* and abstract account of ontological reduction. Gillett and company might still try to claim that nonetheless these relations are the basis for ontological or explanatory reduction in much of the biological sciences. Maybe their claim is that while the quantum is too weird to take seriously, the trusty biological sciences clearly rely on ontological reduction via composition and realization. There is both an explanatory and an ontological dimension to this claim. Philosophers of biology and neuroscience certainly agree that mechanistic explanation is the norm in the biological sciences. And Gillett calls his composition and realization account of explanation 'mechanistic', so is this an affirmation of his claim? Unfortunately no, because while neo-mechanists might not agree about all the details, they *all* agree that the kind of ontological reduction involved in mechanistic explanation is decidedly diachronic and not synchronic (Chemero and Silberstein 2008; Bechtel and Richardson 2010). The reduction of a higher-level mechanism to a lower-level mechanism is not about composition and realization in Gillett's synchronic or non-causal sense of those terms, it need not even always be about reducing one level to a lower level in the spatial or length-scale sense of level (Craver 2007). The point here is that neither localization nor decomposition (the central methodology and metaphysics of mechanistic explanation) entails either composition or realization in Gillett's sense of these terms (see also Love and Hüttemann 2011). It is also worth noting again that some explanations of complex biological systems, such as those in Systems-Biology and Systems-Neuroscience, seem to violate even localization and decomposition (Chemero and Silberstein 2008; Silberstein and Chemero 2011; Sporns 2011). Even staunch neo-mechanists such as Bechtel and Richardson (2010) acknowledge that, for example, given the right types and degrees of non-linearity in complex biological systems, localization or decomposition might fail.

Gillett might argue that even if his account does not reflect actual *explanatory* practice in the biological sciences that physics overall is committed to this *ontological* picture of composition and realization. That is, he might claim that no matter how extended in space and time, no matter how multi-leveled a mechanism turns out to be at the strata of explanation in the biological sciences, physics tells us all mechanisms ultimately have the properties they do because of composition and realization relations. He even provides a quote from the Nobel Prize winner Steven Weinberg to this effect (25). However, later in a 1995 article Weinberg (1995, 111–112) further distinguishes between 'grand' and 'petty' reductionism:

> We first of all ought to distinguish between what…I like to call grand and petty reductionism. Grand reductionism is what I have been talking about so far—the view that all of nature is the way it is (with certain qualifications about initial conditions and historical accidents) because of simple universal laws, to which all scientific laws may in some sense be reduced. Petty

> reductionism is the much less interesting doctrine that things behave the way they do because of the properties of their constituents: for instance, a diamond is hard because the carbon atoms of which it is composed can fit together neatly. Grand and petty reductionism are often confused because much of the reductive progress in science has been in answering what things are made of, but one is very different from the other. Petty reductionism is not worth a fierce defense. Sometimes things can be explained by studying their constituents—sometimes not…In fact, petty reductionism in physics has probably run its course…It is also not possible to give a precise meaning to statements about particles being composed of other particles. We do speak loosely of a proton as being composed of three quarks, but if you look very closely at a quark you will find it surrounded with a cloud of quarks and antiquarks and other particles, occasionally bound into protons…It is grand reductionism rather than petty reductionism that continues to be worth arguing about.

Weinberg's 'petty reductionism' is Gillett's composition and realization relations, and the previous quotation makes it clear what Weinberg thinks of them. Thus, Gillett's 'metaphysics of science' approach accurately captures neither microphysics nor the biological sciences.

The goal has been to use these three collected volumes to provide insight into the current state of the emergence/reduction debate in the early twentieth first century. Secondly, hopefully the readers of this review will be persuaded to rally around a particular conception of the science-first approach that avoids any a priori biases toward extreme forms of monism, pluralism, reductionism or emergence. While many of us hope that such a science-first approach will eventually reveal the grand structure of reality, in order to avoid the scholasticism of the past, we must be very patient and diligent in our pursuit of specific empirical cases across all the scientific disciplines. After all, at the end of the day, confirming or disconfirming grand metaphysical hypotheses such as physicalism, must be done one key case at a time. However, within and across the sciences, we should be looking for opportunities for unification and integration, both methodologically and metaphysically. To that end, let me close by suggesting that getting clear on exactly what kind of emergence/reduction is implied by cases of universality, phase transitions, spontaneous symmetry breaking, etc., ought to be a research priority, as these concepts and formal methods that began their life in physics are now prevalent throughout the special sciences such as Systems-Biology and Systems-Neuroscience. Furthermore, they constitute the formal and conceptual foundations of so-called complexity theory, which is as close to 'emergence studies' as we can get at the moment.

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