Abstracts for the 31st Boulder Conference on the History and Philosophy of Science

Paul Humphreys, *Transformational Emergence*

Much of the contemporary literature on emergence is concerned with synchronic accounts, in part because of the traditional contrast between emergence and reduction, the latter being taken to be a synchronic or atemporal relation. Diachronic forms of emergence are better suited to capturing a different historical thread going back to Mill's heteropathic laws and, later, G.E. Moore's arguments against internal relations. I shall argue that diachronic emergence occurs when certain invariance conditions are violated as a result of cross-temporal transformations in a system. This account generalizes fusion emergence, captures at least one central example in the social sciences, and connects with a recent generalization of Rueger's topological approach by Guay and Sartenaer.

Jessica Wilson, *Threading the Needle between Scientism and OverAbstractionism in the Metaphysics of Emergence*

Natural reality appears to have a leveled structure, on which higher-level entities and features depend on and yet are to some extent autonomous from lower-level, ultimately physical goings-on. The notion of metaphysical emergence aims to capture and illuminate this distinctive combination of dependence and autonomy; yet in spite of a large literature spanning several decades, it remains unclear whether there is available a conception of such emergence that is both systematic and illuminating. In this talk I'll lay out certain desiderata on a metaphysical account of emergence, and canvas approaches to emergence that, I argue, are either overly scientistic, in merely canvassing or taxonomizing scientific cases of seeming emergence, or overly abstractionist, in offering broadly primitivist conceptions of emergence that are incapable of substantive illumination. I'll then offer an intermediate alternative which is both scientifically informed and metaphysically revealing.

Michael Hermele, *Phases of matter as emergent phenomena*

Many of us learned in school that solid, liquid and gas are the three phases of matter. In fact, there are many more, and a major goal of modern condensed matter physics is to classify and characterize phases of matter, and to discover new phases. Phases of matter are characterized by robust, universal properties that are well-defined only for macroscopic systems, and are thus crucial examples of emergent phenomena in physical systems. In this talk, I will attempt to convey how theoretical condensed matter physicists think about emergence, using examples drawn from the study of phases of matter.

Nora Berenstain, *Strengthening Weak Emergence*

Bedau's seminal (1997) "Weak Emergence" introduces a metaphysically realist but 'innocent' picture of emergence by identifying macrostates of a system as weakly emergent if they cannot be derived from the system's initial state and its dynamics except by simulation. The view is open to criticisms from two camps: 1) those who are skeptical of the view's innocence and its compatibility with physicalism, and 2) those who question whether the picture of emergence provided is truly a metaphysical one. I focus on improving Bedau's account in light of criticisms from the second camp.

Wilson (2013) argues that Bedau's view cannot be seen as characterizing emergence in metaphysical rather than merely epistemological terms, as the nonderivability of a nonlinear system's macrostates is compatible with the ontological reducibility of its macrostates to its microstates. I suggest that Bedau identifies an important connection between weak emergence and nonlinear systems whose macrostates cannot be predicted except by simulation, but he misidentifies the non-derivability of the system's behavior as the singular source of its weak emergence. I argue that Bedau needs to add a criterion of algorithmic compressibility to his picture in order to produce a substantive, metaphysically realist account of weak emergence. Rather than nonderivability alone guaranteeing that some system's macrostates are weakly emergent, it is the non-derivability plus the algorithmic compressibility of the system's macrostates that make them weakly emergent.

The improved picture of weak emergence that I suggest draws from two separate metaphysical pictures, both of which are explicitly anti-emergence. The first is Dennett's (1980) Real Patterns, which like Bedau's picture, tries to make sense of seemingly emergent object that arise within the cellular automaton of Conway's Game of Life. The criterion of algorithmic compressibility is the focus of Dennett's Real Patterns view. He takes his picture to be neither reductionist or emergentist, and he claims to be walking a line between realism and anti-realism. But his view backslides into instrumentalism, as he takes facts about algorithmic compressibility to be inherently interest-relative. The second is Ladyman & Ross's (2007) information-theoretic structural realism, which also draws from Dennett's Real Patterns picture. Ladyman and Ross add a criterion of projectibility and a criterion of non-redundancy in order to develop Dennett's view into realist criterion of ontological reality.

I suggest that by adding a criterion of compressibility to Bedau's account of emergence based on non-derivability, we approach something similar to the picture that Ladyman and Ross outline in (2007), which they call information-theoretic structural realism. However, if we take their criteria to characterize the phenomenon of weak emergence rather than to offer a principle of ontology, then we need not be committed to ontic structural realism. Ladyman and Ross take themselves to be offering a real-patterns criterion of ontology and reject emergence. The spirit of their view, however, is very much in line with weak emergence, as it is motivated in part by a desire to take seriously the methods and domains of the special sciences and to not foreclose on the reality of their laws and objects because of a theoretical commitment to reductionism. The same considerations are motivations for Bedau's original view as well as for the improved version that I suggest.

Kevin Morris, ***Truthmaking, Levels of Reality, and the Mysteries of Emergence***

The concept of truthmaking, the idea that when a statement or representation is true, there is typically something about the world in virtue of which it is true, has garnered considerable interest in recent metaphysics. Often, the motivation has been the thought that truthmaking can provide a new perspective on some important issue or debate. Thus it has been claimed that the concept of truthmaking can be used to advance debates over realism, ontological commitment, fundamental reality, physicalism, and levels of reality; to catch "ontological cheaters"; and to delineate metaphysical issues from linguistic ones.

This paper evaluates the suggestion that the concept of truthmaking, and a concept of fundamentality cashed out in terms of truthmaking, can play a substantive role in defining an unproblematic notion of emergence. In particular, despite playing an important role in both philosophical and scientific discourse over the past 100 years, it has often been thought that there is something obscure about the concept of emergence, and that it is problematic to claim that there are truly emergent features. Ross Cameron and Elizabeth Barnes, however, argue that the more pressing concerns arise from characterizing emergence in terms of a levels-based ontology in which emergent features are taken to be "higher level", and that once emergent features are instead characterized as those that, while ontologically dependent are yet needed as truthmakers, the standard problems for emergence can be resolved, where "ontological dependence" amounts to the impossibility of independent or "lonely" existence.

There is reason to doubt, however, that the notion of truthmaking can play a key role in formulating an unproblematic notion of emergence. This paper focuses on two important concerns about emergence—the problem of "ontological weight" or "emergent novelty" and the problem of emergent causal efficacy—and how the truthmaking-based concept of emergence addresses these concerns. The central thesis urged here is that that while this concept of emergence may avoid these and some related "mysteries of emergence", and moreover avoids taking emergent features to be "higher level" properties, this is largely if not entirely in virtue of its utilizing a weak sense of dependence; the concept of truthmaking is superfluous when it comes to securing an unproblematic concept of emergence and allowing the defender of emergence to dispense with "levels of reality". Moreover, it appears that while the concerns and puzzles of interest, despite not applying to emergent properties as such in the truthmaking-based sense, can be reformulating for a subset of such properties, namely those taken to depend on other properties in a more robust sense. Likewise, there is reason to doubt, contra Cameron and Barnes, that once emergence is understood in the manner that they propose, the defender of emergence may remain "blissfully neutral" on whether and to what extent emergent properties supervene on other aspects of the world.

Despite thus appearing to play a negligible role in securing an unproblematic concept of emergence, and one that does without "levels of reality", this paper concludes by arguing that truthmaking may yet be able to play an important role in understanding physicalism and other austere metaphysical outlooks, and in characterizing an attractive middle ground between reductive and nonreductive physicalism. In particular, when it comes to understanding emergence, the key truthmaking-based concept is that of being needed as a truthmaker; here, however, truthmaking does nothing to dispense with "higher level" properties or "levels of reality" and the work is rather done through weakening the sense in which emergent properties are taken to be dependent. In contrast, when it comes to understanding physicalism and other austere outlooks, the crucial truthmakingbased notion is instead that of not being needed as a truthmaker. In this context, the role of truthmaking consists not in securing the "ontological weight" of some properties, but rather in securing a sense in which some properties lack such weight. That is, the role of truthmaking consists in providing a way of dispensing with superfluous levels and properties that would occupy those levels, rather than in legitimizing properties or features that are presumed not to be superfluous. While this role for truthmaking—the role that it may be able to play in dispensing with properties not needed as truthmakers, and so any "levels" that they might be thought to occupy—has been subjected to important criticisms, the modest thesis here defended is that whether or not truthmaking can play a substantive role in this context is quite independent from the rather insubstantial role that it can seem to play in developing an unproblematic and yet recognizable concept of emergence.

Fatema Amijee, *Emergence and Metaphysical Explanation*

Are emergent entities metaphysically explained? A prima facie answer is 'no'. After all, most accounts treat emergent entities as fundamental, and traditionally, an entity is fundamental just in case it isn't metaphysically explained. My goal in this paper is to argue that this result is the product of a mistaken identification of the fundamental with the metaphysically unexplained. Once we abandon this identification, we can straightforwardly show that emergent entities are both fundamental and metaphysically explained. I will proceed as follows. I will first provide a positive characterization of metaphysical explanation, and explain how it differs from causal explanation. Next, I argue against identifying the fundamental with the metaphysically unexplained, and provide an alternative account of the fundamental. Finally, I show how emergent entities are metaphysically explained.

Olivier Sartenaer, *A New Look at Emergence. Or When After is Different*

During the last two decades or so, the concept of emergence has relentlessly gained in credibility and scope across the full spectrum of the natural sciences and, correspondingly, debates about it have grown in depth and intensity in the various sub-fields of philosophy of science. Yet, current discussions about emergence seem to have reached a stalemate: either they revolve around crafting a metaphysically-inclined notion that is philosophically fruitful but leads to insuperable issues – among which failing to have a well-defined empirical support –, or they verge on devising scientificallyinclined notions that are empirically unproblematic but somehow philosophically shallow.

The proposed talk is about breaking this deadlock, by putting forward a new account of emergence that is metaphysically kosher and empirically well-supported, while being able to keep untouched the main philosophical intuitions that lie behind the classic picture of emergence. Such a new account, inspired by Paul Humphreys' recent (unpublished) suggestion and referred to as “transformational emergence”, encapsulates an unprecedented perspective shift from the most widespread, hierarchical and synchronic construal of emergence – according to which “More is different” –, to a new, non holistic and diachronic approach – in the light of which “After is different”.

The proposed talk will address the cooking up of transformational emergence through three successive steps. First, a metaphysical account will be provided on the basis of a specific construal of the conciliation of the two usual tenets of any particular version of emergence, namely dependance (of the emergent E on its basis B) and novelty (of E with regard to B). Considering S1 and S2 as being successive states of a given system S at times t1 and t2, one will say that S2 transformationally emerges on S1 iff:

• (dep) S2 is the product of a continuous process going from S1 (for example causal, and possibly fully deterministic). In particular, the “realm” R to which S1 and S2 commonly belong (e.g. the physical realm) is closed, to the effect that nothing outside of R participates in S1 bringing about S2. And yet:

• (nov) S2 exhibits new entities, properties or powers that do not exist in S1, and that are furthermore forbidden to exist in S1 according to the laws {Li1}ni =1 governing S1. Accordingly, in addition to these laws, different laws {Li2}mi =1 govern S2.

Nina Emery, *Deterministic Chance as Emergent Chance*

Compatibilism about chance and determinism—the view that there are non-trivial chances in worlds where the fundamental laws are deterministic—has been gaining in popularity among philosophers of science and metaphysicians. (See, e.g., Loewer 2001, Maudlin 2007, Ismael 2009, Glynn 2010, Emery 2015). Paradigm cases of deterministic chance involve non-fundamental systems. However many advocates of compatibilism think that facts about deterministic chance are in some sense reducible to facts about the fundamental physics. In this paper, I argue that these reductive accounts face serious problems. Furthermore, there is good reason to think that at least some facts about deterministic chance are not derivable, even in principle, from fundamental physics. In other words, I argue that at least some facts about deterministic chance are strongly emergent with respect to fundamental physics. If the argument works, deterministic chance is a novel type of strongly emergent phenomena.

The paper begins by reviewing several reasons for thinking that deterministic chances exist, with a particular emphasis on the explanatory role that such chances appear to play in some of our best scientific theories. I then argue that in order for deterministic chances to play the relevant explanatory role, they must have a robust modal component. Facts about deterministic chance do more than just explain what actually occurs; they do so in a way that underwrites beliefs about what would occur (or at least: what would be likely to occur) in various counterfactual situations.

In the second part of the paper I argue that facts about deterministic chance cannot be reduced to facts about fundamental physics. I consider three suggestions for such a reduction. According to the first suggestion, facts about deterministic chance are reducible to facts about the actual initial condition of the universe (this is one way of reading Schaffer 2007). According to the second suggestion, facts about deterministic chance are reducible to facts about which initial conditions of the universe are probable (see, e.g., Albert 2000 and Loewer 2001). According to the third, facts about deterministic chance are reducible to facts about which initial conditions of the universe are typical (see, e.g., Maudlin 2007). I argue that these suggestions either face significant conceptual problems or fail to play the explanatory role outlined in the first section.

In the third part of the paper I argue that the considerations already set out can be used to argue for an even stronger conclusion. They can be used to argue that facts about deterministic chance cannot even in principle be derived from facts about the fundamental level. Any conceptually coherent candidate derivation base is amodal, and the sort of robust modal component that characterizes deterministic chance cannot be derived from an amodal base. Facts about deterministic chance are thus strongly emergent with respect to facts about the fundamental level.

In the fourth part of the paper I show how an account of deterministic chance as a (strongly) emergent phenomena can be developed in either of two ways. According to the first account, deterministic chances are emergent properties of macroscopic experimental set-ups. According to the second account, deterministic chances are sui generis emergent entities.

Joshua Rosaler, *Local Reduction in Physics*

According to the most commonly told story about the progress of physics, successive theories in physics come ever closer to revealing the true, fundamental nature of reality. This convergence rests on the supposition that later theories bear a special relationship to their predecessors often called “reduction,” which minimally requires one theory to encompass the domain of application of another. More specifically, the conventional wisdom tells us that Newtonian mechanics reduces to[1] special relativity, special relativity to general relativity, classical mechanics to quantum mechanics, quantum mechanics to relativistic quantum mechanics, relativistic quantum mechanics to quantum field theory, thermodynamics to statistical mechanics, and more. Given the extent to which this conventional wisdom and its constituent reductions are widely taken for granted by physicists and advertised to the wider public as established fact, one could reasonably surmise that the these reductions had long ago been worked out and tidied away for anyone who might care to learn their details. However, a closer examination of the literature on many of the specific reductions that the conventional wisdom takes for granted reveals that our understanding of these inter-theory relations is patchy, conjectural and often far from consensus. Arguably, the most serious obstacles to placing these reductions on firmer foundations are more philosophical than mathematical: namely, they are problems of how to articulate in a precise and testable way what reduction requires, both in these particular cases and more generally.

In his influential 1973 paper, Nickles identifies two attempts to articulate the meaning of the term "reduction" in the context of inter-theory relations in physics. The first descends from Ernest Nagel’s seminal account of reduction while the second

[1] Here I Employ the “philosopher’s” convention in which a less encompassing theory “reduces to” a more encompassing one, rather than the “physicist’s” convention, which is the inverse of this.

originates in the approach commonly employed by physicists that requires one theory to be a "limit" or "limiting case" of another. Since Nickles' paper, these two accounts have tended to dominate philosophical discussion concerning issues of the general methodology of reduction in physics. As commonly presented, both strongly suggest - and in some cases, state explicitly - that reduction between theories in physics should rest on a single "global" derivation of a high-level theory's laws from those of a lowlevel theory. Here, I argue by means of a particular example that global reduction is not always available in cases where the conventional wisdom requires reduction to hold and reiterate the more general point that global reduction (whether in physics or other contexts) is often incompatible with multiple realization. Importing a strategy that has been adopted by a number of authors in the philosophy of mind, I argue that it is possible to a define a weaker "local" concept of reduction in physics that suffices to uphold the conventional wisdom by ensuring the subsumption of one theory's domain by another while addressing a number of difficulties with global approaches, including problems with multiple realization. This notion of reduction is "local" in the sense that it permits the reducing theory to account for the reduced theory's success through numerous context-specific derivations that are relativized to different systems in the high-level theory's domain. Crucially, these derivations concern the specific models of the two theories that are used to describe a single fixed system, rather than the theories as a whole.

This paper has two main goals, which are mutually supporting. The first is to motivate and develop a local account of inter-theoretic reduction in physics. Intertheoretic reduction in physics, understood minimally as the requirement that one theory subsume the domain of successful application of another, does not require anything as strong as global reduction directly between theories; local reduction suffices for this purpose, and moreover does not have the difficulties accommodating multiple realization that global approaches do. I then argue that local reduction between theories should be understood in terms of the more basic notion of reduction between two models of a single fixed system. The second goal is to illustrate what is meant by fixed-system, inter-model reduction by giving an account of this concept in two sets of cases: first, where both models of the system in question are dynamical systems, and second, in cases where one or both of the models is stochastic in nature. I show that such cases can be analyzed in terms of a certain model-based adaptation of the Nagel/Schaffner approach to reduction. I further show that this broadly Nagelian analysis of inter-model reduction encompasses many cases that have been cited as instances of "physicists'" limit-based notion of reduction, as well as providing a more precise characterization of these cases than do existing formulations of the limit-based approach. In addition, I suggest how this model-based adaptation of the Nagel/Schaffner approach might be extended to fixed-system, inter-model reduction involving other kinds of model. Finally, I argue that this local, model-based account of inter-theoretic reduction in physics is consistent with the phenomenon of multiple realization and with certain forms of "weak" emergence.

Robert Parson, *Is Molecular Structure an Emergent Property? A physical chemist's perspective*

The early success of quantum mechanics in describing the spectra of simple atoms and molecules led many to conclude that chemistry had been reduced to physics. In an oftquoted sentence, Dirac (1929) said: "The underlying physical laws necessary for the mathematical theory of a large part of physics and the whole of chemistry are thus completely known, and the difficulty is only that the exact application of these laws leads to equations much too complicated to be soluble." In subsequent decades, there has been a reaction against this triumphalist attitude. Both scientists and philosophers have argued that fundamental concepts in chemistry, such as the structure of a molecule, are not derivable from the quantum mechanics of electrons and nuclei in a straightforward fashion. Molecular structure only appears when the adiabatic or "Born Oppenheimer approximation is invoked, which has led some to conclude that structure is an emergent property that is inserted "by hand" into quantum chemical calculations. In this talk, I will first outline the procedures that contemporary chemists, including both experimentalists and theoreticians, use to determine the structure of a molecule. I will argue that practitioners actually work with several different concepts of "structure" that are appropriate in different circumstances. I will then describe some conceptual difficulties that arise when carrying out this program. One of these is "Hund's paradox": if, as is generally believed, electromagnetic forces are sufficient to describe the interactions of electrons and nuclei on the scales relevant to chemistry, then the stationary states of a molecule should have a definite parity, which would appear to imply that optical isomers (molecules existing in definite right-handed or left-handed structures) should not exist. I will discuss various approaches taken by physicists and chemists to resolve this conundrum. Typically, these involve spontaneous symmetry breaking and/or environmentally-induced decoherence, and thus link this dilemma to fundamental problems in quantum physics. Finally, I will discuss chemical processes in which the Born-Oppenheimer approximation breaks down completely, for which one could argue that the classical concept of molecular structure does not apply. Recent experimental and theoretical work suggests that such processes are involved in photosynthetic energy transfer, so this question is of more than academic interest.

Vanessa Trivino, *Emergent properties in biology: the case of fitness*

According to the thesis of the unity of science, all of the so-called special sciences biology, sociology, psychology…can be reduced, at least i n principle , to what is considered to be the most fundamental one, i.e., physics (Oppenheim and Putnam, 1958; Schaffner, 1967b, 1969a; Waters, 1994). Reductionism is, therefore, the criterion that each special science should meet to be properly considered as a science.

The thesis of the unity of science based on reductionism has been challenged from different perspectives (e.g. Fodor, 1974; Kitcher, 1984; Mayr, 1982, 1988). Here I will focus on the arguments against reductionism given by the evolutionary biologist Ernst Mayr. According to Mayr, there is a plethora of phenomena and concepts (e.g. "population, species, adaptation, digestion, selection, competition, and the like") without equivalent in the physical sciences (Mayr, 1982, 34).

Among these phenomena that cannot be reduced to physics, Mayr focuses on the emergent properties of biological phenomena. According to Mayr, emergent properties show that to defend the unity of science we do not need reduction. Rather, what we need is to extend what we understand by science, so that biology and physics could be considered as being sciences in the same sense. However, Mayr’s antireductionism needs to confront the metaphysical problem about whether there are emergent properties and how they should be characterized.

In this paper, I will tackle this issue (namely, the existence of emergent properties in biology) by attending to the main concept in classical evolutionary biology: the notion of fitness. I start by analyzing the advantages and disadvantages of the different definitions of fitness, including the actualist definition and Rosenberg´s supervenient account of fitness. After presenting some objections to Rosenberg's proposal, I introduce my own definition of fitness as a causal dispositional property. Second, I will focus on analyzing the emergent character of fitness by seeing whether it meets the main features that metaphysicians have attributed to emergent properties.

Igor Gasparov, *Emergent dualism and the challenge of vagueness*

Dean Zimmerman has recently argued against “garden variety” materialism and in support of emergent substance dualism (Zimmerman “From Property Dualism to Substance Dualism,” Proceedings of the Aristotelian Society Supplementary Volume 84 (2010), 119–150). According to Zimmerman, if you believe in the existence of phenomenal properties, it is difficult to embrace garden variety materialism. This is so because among entities suggested by garden variety materialism there are no appropriate candidates for being the subject of my conscious experiences since all “natural” material parts of my organism are vague. For such reasons Zimmerman claims that emergent dualism should be back on the table. Unfortunately, emergent dualism is vulnerable to the very problem of vagueness that makes trouble for garden variety materialism. As a remedy for the vagueness problem Zimmerman has proposed what I call the Overdetermination Hypothesis. According to it, many overlapping sets of neural events may generate only one single soul so that the vagueness is avoided. In the paper I will argue that the Overdetermination Hypothesis is also afflicted with two serious problems.

The first is that either Zimmerman's appeal to overdetermination is ad hoc or a garden variety materialist could invoke it as well. Indeed why should we suppose that many distinct and precise causes yield just one precise effect, rather than many? Is there any reason that convincingly speaks in favor of this supposition, beyond the need for a single subject of conscious experience?

Consider the case when two or more bullets simultaneously do cause just one single hole in a wall. At first glance, it appears in this case that many distinct precise events jointly cause just a single event. The problem, however, is that each of the distinct bullets would cause its own part of the destruction in the wall. The talk of many bullets causing one hole is imprecise. At the fundamental level each precise cause is related to its own precise outcome. Applying this claim to a hypothetical process of soul generation, it seems to follow that whenever there is a distinct precise physical cause sufficient for the production of a soul, that cause should yield its own precise outcome. Thus, many distinct precise brain processes each lawfully sufficient for the generation of an emergent soul should and presumably would produce many distinct souls rather than just one.

Still, if one is willing to accept the Overdetermination Hypothesis, why not say that many precise neural events overdetermine just one single physical entity,—the brain*,—that is the unique bearer of the precise phenomenal properties? If the overdetermination of the soul should be allowed, why shouldn't the overdetermination of its physical counterpart? For this reason a proponent of garden variety materialism could claim that the brain* is neither vague nor identical to any of equally eligible candidates for being the brain. So, I think, a proponent of the Overdetermination Hypothesis is confronted with a dilemma: Either she has to acknowledge that the overdetermination solution is ad hoc or concede that a garden variety materialist may invoke it as well to bolster her position.

Second, there seems to be another, more serious problem for the Overdetermination Hypothesis, one that concerns the precise temporal beginning of an emergent soul. According to the Overdetermination Hypothesis, many overlapping patterns of neural firing causally overdetermine the existence of my soul. But patterns of neural firing can overlap in time as well as in terms of the physical particles which they involve. Because these patterns of neural firing contain so many constituent sub-events (at the atomic or sub-atomic level), and because these processes are unlikely to have clear-cut temporal beginnings or endings (times at which we could say, the relevant process starts exactly now, and ends exactly...now), it is very likely that for any pattern of neural firing which is a good candidate for being a pattern sufficient for the generation of a soul, there will also be many other equally good candidates that begin or end slightly earlier or slightly later.

But it appears that any emergent soul must necessarily have a beginning in time, because it is the result of natural causal processes occurring over time. Moreover, an emergent soul, in order to be a non–vague entity, should have a precise time of temporal beginning. Let t' be the precise time at which my emergent soul s began to exist. From this it would follow that no neural activities sufficient to produce s occurred before t'. But this should strike us as very unlikely, for the reason given in the previous paragraph. Any pattern of neural firing which is a good candidate for being the first neural process to generate my soul will likely be just one among very many processes which have slightly different times of initiation or termination, but which are nonetheless equally good candidates for being a process sufficient for the generation of a soul. If it was a problem for the garden variety materialist that, at a single time, there are many equally good candidates for "the physical object which is my brain", then it should be just as much of a problem for the emergent dualist that, occurring at slightly different times, there are many equally good candidate processes for "the neural process which first generates my soul".

Thus, I conclude, the main source of the difficulties which afflict emergent dualist account of the subject of conscious experience is the lawful causal dependence of the emergent soul on the physical processes going on in the brain. The feature, which the emergent dualist believes to be an advantage of her account, enabling her to include the soul in the natural order, turns out instead to be a "Trojan horse" through which the problem of vagueness casts its shadow on the soul, making it inappropriate for being the unique bearer of my conscious experience.

Marco Nathan, *'Emergent' Complexity in Neural Networks: A Pragmatist Approach*

The core idea underlying the notion of emergence is that, as systems become increasingly complex, they display novel properties that, in some sense, transcend the properties of their constituent parts and exhibit behavior that cannot be predicted on the basis of the laws that govern simpler systems. Such ideas are hardly new, tracing their roots (at least) back to J.S. Mill's distinction between 'heteropatic' and 'homopathic' laws, and have been developed, in their current form, early in the 20th century by philosophers such as Broad, Alexander, and Lovejoy, and scientists like Morgan and Sperry. Set aside during the heyday of logical positivism, which dismissed its core ideas as confused and incoherent, over the last few decades, emergence has made its way back into philosophical and scientific debates as an influential form of 'non-reductive materialism.'

The return of emergence on the main stage has had a polarizing effect, dividing the camp between enthusiastic defenders and skeptical naysayers. One of the most influential critics has been Jaegwon Kim who, in a series of essays, has adopted a deflationary stance, casting doubt on the soundness of the notion of emergence itself (Kim 2010). While an exhaustive discussion of Kim's arguments lies beyond the scope of this article, we can summarize his main point as follows. Kim begins by defining 'emergent properties' as features that, unlike properties that are merely 'resultant,' are not explainable, predictable, or reducible to the lower-level conditions out of which they emerge—the so-called 'basal conditions.' Kim goes on to identify emergent properties with irreducible ones, claims that irreducible properties are neither predictable nor explainable on the basis of underlying processes (as per the emergentist thesis), and argues that the functionalization of a property is both necessary and sufficient for its reduction. The problem, Kim says, is that, on this characterization, emergentism turns out to be an empty doctrine for, he argues, all properties are either physical or reducible to physical properties via functionalization.

While Kim and various other authors dismiss emergentism, the notion of emergence continues to be extensively used not only in philosophy, but also in science. For instance, in a recent monograph, cognitive neuropsychologist Bruce Pennington (2014, 229) defines emergent properties as "new properties in a system that are not strictly reducible to individual elements of that system." His examples include water, whose physico-chemical properties are quite distinct from the properties of either hydrogen or oxygen, isomers, organic molecules with identical chemical compositions but specular structures which affect their interaction with other molecules, the tertiary structure of protein, functional properties of the nervous system such as language or face recognition and abnormal behavior. Similarly, building on the basic observation that collective interactions among the elements of complex network systems often give rise to new properties that do not exist at lower levels or organization, Olaf Sporns (2015, 92-93) identifies 'emergence' as a key concept in network neuroscience. As examples of emergent phenomena, he cites global states of brain dynamics in which large populations of neurons engage in coherent and collective behavior. For instance, he considers the phenomenon of neural synchronization, the coordinated firing 'in sync' of large numbers of nerve cells which is not attributable to any specific causal chain of interactions in a circuit model, but is the global outcome of many local events orchestrated by the network as a whole.

Are scientists mistakenly employing an obscure notion that (some) philosophers righty dismiss as incoherent? Or does the extensive use of emergence in science show that theoretical critique misunderstands its role in scientific practice? Neither option, I maintain, is palatable. In this article, I suggest a way out of the dilemma by proposing a ‘pragmatic’ analysis of emergence. I begin by arguing that, recent arguments notwithstanding, the way emergence is commonly employed in science does not correspond to current philosophical definitions. In line with Kim’s argument, the physico-chemical properties of water, the tertiary structure of a protein, and neural synchronization are perfectly predictable, explainable, and reducible (via functionalization or explanation) to basal conditions—indeed, that seems precisely what makes them significant for scientific practice, where unexplainable and irreducible proprieties play little to no role. What makes a property emergent is not its ‘irreducibility’ but, rather, its extrinsic relation to its basal condition: a property is emergent if it necessitates a shift in level of organization, that is, if a new system of concepts is required to explain nature of this property and its role in the system. I motivate this definition by discussing examples from systems biology, network neuroscience, and cognitive neuropsychology. Finally, I draw some philosophical conclusions regarding my proposed definition. Specifically, I argue that, in order to accommodate the use of emergence in much scientific practice we ought to abandon a metaphysical or ontological perspective—according to which ‘emergence’ is an intrinsic and absolute priority of an object—in favor of an epistemic or more pragmatist approach that treats a property as ‘emergent’ only relative to a given frame of reference. However, contrary to both classic and recent epistemic philosophical accounts (e.g., Hempel and Oppenheim 1965; Taylor 2015), the ‘emergence’ of a property has nothing to do with obscurity or lack of explanation. I conclude by connecting my account of emergence to some mainstream positions in metaphysics and philosophy of science, such as Kim’s ‘conceptual’ approach to downward causation, or Russell’s notion of a causal process.