# Emergence: conceptual and philosophical aspects

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Robert Batterman Piers Coleman Nigel Goldenfeld Eleanor Knox James Ladyman
Elena Castellani Alexandre Guay Angelo Vulpiani Martha Lewis Stephen Blundell Max Cooper

Organizers: Jay Armas, Jeremy Butterfield, Sebastian De Haro, Klaas Landsman

## Contributed talks

### Alex Moran, University of Cambridge, PhD Student

### Emergentist and Non-Reductive Views: Is There A Real Distinction?

My talk focuses on the question: what is emergence? I offer a novel answer that connects the notion of emergence with that of metaphysical grounding. For concreteness, I focus on emergentism about the mental and physical, and contrast this with non-reductive physicalism cast in terms of metaphysical grounding. (Thus 'non-reductive physicalism' is to be understood throughout as the view that each mental property is grounded by some physical one.) The question is whether there is anything to distinguish these views. And if there is a distinction here, how exactly is it to be made precise? I will present three main arguments in the talk, which are as follows:

1. The first argument is that we can draw a clear contrast between (i) a traditional form of emergentism and (ii) non-reductive physicalism by distinguishing supervenience and grounding. Here the emergentist states that the mental properties supervene on the physical ones, whilst the non-reductive physicalist says that the mental properties are grounded in the physical ones. Importantly these claims are not equivalent. Nor is it clear what their entailments are. Certainly, the supervenience claim does not entail the grounding claim. And whilst many grounding theorists would say that the grounding claim entails the supervenience claim, I would dispute even that, and indeed have done in other work. I argue too that this form of emergentism is problematic. First, supervenience relations cannot obtain without 'backing' (Horgan 1993). Otherwise, we have brute necessary connections between distinct existences that go unexplained. Yet the only apposite backing relations are identity and grounding. So now a dilemma arises. If we appeal to identity, we move from emergentism to reductive physicalism. Yet if we move appeal to grounding, we are back with non-reductive physicalism and hence have yet to distinguish this view from emergentism. The second problem is that any 'bare supervenience' form of emergentism fails to really capture the emergentist position. For the supervenience of one set of properties on another cannot be all there is to the emergence of the one set of properties from another. Just as it's exactly right to say that supervenience is in-sufficient for grounding, so it is exactly right to think that a supervenience is in-sufficient for emergence, and that just as 'mere supervenience' claims fail to capture what we mean by grounding claims, so too 'mere supervenience'

claims fail to capture what we mean when claiming that one set of properties emerges from another.

2. The second argument is that one could introduce a form of emergentism by taking the notion of emergence as brute—just as many take the notion of grounding (for instance) as brute. The trouble here, however, is that one faces a substantial task when introducing a new primitive. Grounding theorists have done much to meet this task; offering examples of grounding, explicating the logical and formal properties of the grounding relations, and even devising entire 'logics' for the notion of ground. The point is not that one could not do this with emergence, but that since this is a rather substantial task, it is not enough just to introduce emergence as a basic bit of ideology and leave it at that. I suspect, moreover, that as one tried to explicate the emergence construed as a primitive one would end up with something very like grounding. This, in fact, fits very nicely with my next and final argument. But the central point here is that 'going primitive' seems like an unpromising strategy for distinguishing emergentist from non-reductive views.

3. My final argument is that there is in fact no 'real distinction' between non-reductive physicalism and emergentism. According to this proposal, we should view the claim that physical properties ground mental ones as both a form of non-reductive physicalism and a form of emergentism. We have a genuinely physicalist view here, because primacy is given to the physical: the physical properties ground the mental ones. But we also have a genuine form of emergentism, since grounding is a generative relation. Specifically, the fact that grounding is a generative relation means that if the physical properties ground the mental ones, (so that each mental property is grounded by some mental one, whilst the con-verse fails), then the mental arises out of, and so emerges from, the physical. Of course this point easily generalises. Non-reductive moral realism could also be construed as an emergentist view. The descriptive properties would ground the moral ones; and therefore the moral would emerge out of the descriptive. In general, wherever a domain of properties F is grounded by some domain of properties G, we can say that the F-properties are both grounded in and emerge from the G properties.

After this third and final argument, the talk closes with the following speculative claim. Many philosophers are attracted to the view that there is some fundamental set of properties L1, and that there are many other domains of properties at different levels of reality L2, L3, etc., such that the fundamental level grounds all others. We thus end up with a hierarchical picture of reality that is broadly Aristotelian. (Keep in mind that grounding is transitive). What I suggest is that this kind of view, should be seen as both emergentist and ground-theoretic. For on this view, we have the fundamental level, and all other levels that derive from it; but additionally, each derivative level is also emergent, having arisen out of the fundamental base. (Think again of the generative nature of grounding and hence the connection be-tween ground and emergence.) For what it's worth, this strikes me as an attractive picture of reality, especially if the fundamental base is taken to be a physical one. The physical level would take ontological primacy: all else would emerge out of it, and yet also be grounded therein. On this proposal, emergence is just the converse of the grounding relation. The notion of 'in virtue of' is thus invaluable to metaphysics twice-over: not just for capturing grounding claims, but also for capturing claims of emergence.

## Alexander Franklin , King's College London, Postdoc

### How Do Levels Emerge?

Science describes the world at a number of different levels, but controversy remains over what constitutes such levels. In this talk, I offer a novel account of levels, which casts higher levels both as emergent from and reducible to lower-level descriptions. One feature of my account is that levels are defined context-dependently: this has the upshot that top-down causation is ruled out.

I will argue that two descriptions of the world are at different levels if one is predictively and explanatorily autonomous from the other: that is, if prediction and explanation at the higher level may proceed without reference to details required for lower-level descriptions. Following Franklin and Knox (2018), I claim that this establishes the emergence of higher levels: a description is emergent if it leaves out details salient at lower levels, and engenders novel explanations.

Furthermore, levels exhibit partial predictive and explanatory closure: most predictions and explanations at a given level only require reference to other entities or processes at that level. Anti-reductionists of a certain ilk might take such a level structure as given – they would hold that the world is populated with autonomous levels and the level structure is not explicable from the bottom up. Reductionists, if they wish to appeal to a level structure, ought to identify the mechanisms by which the levels arise.

Where the (putatively) higher-level description is autonomous, the dynamics which allow predictions in terms of the higher-level variables will be invariant with respect to perturbations in the irrelevant lower-level variables. While reduction, construed plurally, will also involve the derivation of one theory from another, we have an acceptable reductionist account of levels only if we can also explain the emergence of levels by isolating and identifying features and processes at lower levels which secure the irrelevance of a class of variables with respect to higher-level descriptions.

My view of levels is closely related to the accounts found in List (2018) and Wimsatt (2007). Although our accounts have significant commonalities, I build on their work by articulating the mechanisms by which the level structure arises.

I cash out this account with a simple example: that of a ball bouncing. I argue that the bouncing ball description emerges from the more fundamental atomic description since one can explain and predict future bounces in terms of just a few coarse-grained variables. I contrast this case with that of a bag of bouncy balls and tacks whose bounces sensitively depend on the alignment of its contents; such an object will not be well described by an emergent description in most contexts, and thus will not count as higher level.

It's important to emphasise that my view of reduction does not require a universal foliation into levels. Any levels that might be defined will be patchy and only exist within certain domains under certain conditions. In other words, this account of levels is context-dependent. One interesting consequence of this account is, thus, that instances of top-down causation are ruled out: in any context where one would appeal to goings-on at different scales in order to explain or predict, then, by construction, that will count as the same level. While such levels may be multi-scale, this is consistent with my account. I further articulate this consequence of the account by considering an additional example: that of a scientist directly manipulating a single atom of the bouncy ball. I contend that, while this might be seen as an instance of top-down causation, on my account, both the scientist and the atom are on the same level in the context where one cannot predict or explain the atom's movements except by reference to states of the scientist.

Allowing for multi-scale levels might be seen to pose a challenge to the reductionist account; one might claim that the project of explaining from the bottom up is no longer well defined if levels are constituted in this way. However, I claim that a significant element of the reductionist project is still satisfiable, this involves identifying processes which guarantee the irrelevance of certain variables for higher-level descriptions. In the context of this example, the relevant reduction will explain the processes by which the scientist interacts with an individual atom, while the many degrees of freedom of the environment and apparatus are frozen out. The broader reductionist project then involves articulating how the more generic level structure relates to the particular multiscale levels relevant in this context.

I conclude by arguing that, despite top-down causation being ruled out, my account of levels allows for robust bottom-up explanations of the emergence of levels across science.

## Bixin Guo, University of Southern California, PhD student

### Ontological vs. Theoretical Reduction: A Case Study on Thermodynamics and Statistical Mechanics

The relation between thermodynamics and statistical mechanics has been seen as the most straightforward and canonical instance of emergence or reduction—when one attempts to develop an account of reduction and demonstrate how exactly their account works by using an example, this is usually the first case to which they appeal. However, even in this canonical case, it is not clear (1) what a generally accepted theoretic framework or formalism for statistical mechanics is; (2) what thermodynamics is about; and, most importantly, (3) what reductive relation they bear. Instead of assuming that we have a clear grasp of what thermodynamics, statistical mechanics, and their relation are and developing an account of reduction based on that, I propose another direction to approach the problem: I argue that there are two distinct approaches to understand reduction in general—ontological and theoretical reduction, and either one or the other has been taken as an implicit assumption and in fact shaped our understanding of statistical mechanics and thermodynamics (in particular, the debate on whether the Boltzmannian or the Gibbsian is the correct approach to statistical mechanics to which thermodynamics can be reduced). More specifically, ontological reduction is the more familiar approach to understand reduction: it starts with an ontological relation between different levels (in most cases, a mereological relation)—it presumes, for example, that molecules are made of atoms (or, in mereological terms, atoms are parts of a molecule). As a consequence of this ontological relation, we expect there to be a theoretical relation of reduction between atomic physics and the chemical theories. According to this approach, the fact that one theory can be reduced to another (that is, there exists a reduction relation between two theories) is justified by the relation of the ontology of each theory. The other approach to reduction—theoretical reduction—goes from the opposite direction: we do not presume any fixed belief of the mereological relation between molecules and atoms, but start with only separate theories about them and a mathematical formalism on how to derive chemical theories from atomic physics. In light of this inter-theoretical relation of reduction, we then learn that there is an ontological relation between molecules and atoms (i.e., molecules are made of atoms). Unlike the first approach, ontological relations follow from, are secondary to and depend upon the nature of the theoretical reduction relation. I argue that the arguments for the Boltzmannian approach to statistical mechanics assume and rely on ontological reduction while the Gibbsian approach is better understood via theoretical reduction. For example, it has been argued for the Boltzmannian approach that it characterizes thermodynamic systems and thermodynamic entropy in terms of individual systems, and the Gibbsian approach has been criticized for characterizing them in terms of probability distribution over an ensemble of infinitely many systems, which do not bear a straightforward ontological relation with individual thermodynamic systems in question. Lastly, the paper offers two arguments for why theoretical reduction is preferred as a general approach to reduction, and suggests that theoretical reduction supports a pluralistic view: there can be multiple lower-level theories to which a higher-level theory is reduced (in particular, the Boltzmannian and the Gibbsian approach to statistical mechanics are not incompatible as microphysical descriptions of thermodynamics). In this way, it shows how explicating and clarifying the general account of reduction lurking in the background can help to advance this particular debate concerning statistical mechanics.

## Erica Onnis, University of Turin, PhD student

### Emergence: A Model of Natural Discontinuity

Classical definitions of emergence generally focus on two features: first, irreducibility, and, second, ontological novelty. In the first case, an entity is emergent if its properties cannot be reduced to the properties of its component parts. As a consequence, in this framework, emergent properties are not theoretically predictable, for they do not depend directly on the properties of their parts. In the second case, a phenomenon is considered emergent if it exhibits novel properties not held by its parts, and introduces in reality new powers or causal structures, such as downward causation.

Despite both these definitions describing significant aspects of emergent processes, they raise several problems. On the one hand, as some philosophers of science and scientists have noticed, the widespread habit to identify emergent entities with entities that resist to reduction is nothing more than explaining an ambiguous concept through an equally puzzling notion. Just like emergence, as a matter of fact, reduction is not at all a clear, uncontroversial technical term, and it is used in different ways depending on different contexts. On the other hand, a feature such as qualitative novelty can easily appear to be an observer-relative property, and not an indicator of the ontological structure of the world. Moreover, novel, unexpected, and unusual behavior might always be something that has just not yet been explained and understood in more classical terms.

Therefore, in view of the above, to provide a good model of emergence, other features should be taken into consideration too. The one which I will focus on is the connection between the notion of emergence and that of discontinuity.

What is interesting in the declared incompatibility between emergence and reduction is the difference between the two models of reality underlying them. While reductionism assigns to the structure of reality a mereological, nomological (and in certain cases ontological) continuity, emergentism leaves room for discontinuity instead. The reductionist universe is mereologically composed by a small number of fundamental entities – the (micro)physical ones – and by a huge quantity of combinations or aggregations of them. In this universe, the nature of the macroscopic entities depends upon the nature of the microscopic ones, and no physically independent, freely floating property is admitted. In contrast, accepting the existence of genuine emergent phenomena, implies the claim that the structure of the world is discontinuous both metaphysically and nomologically. Matter is structured in different ways at different scales (of time, energy, size, organisation and so on), and there are several properties which are consequently scale-relative. As a consequence, from a nomological point of view, it seems reasonable to admit that nature is governed by a “patchwork of laws” reflecting heterogeneous natural regularities, rather than by a single set of fundamental laws modelling physical properties alone (whose accurate definition, by the way, remains controversial, as shows the debate about Hempel's dilemma).

In this last framework, emergence represents the specific trait had by macroscopic entities showing scale-relative properties and their relevant powers, which depend upon the organisational constraints of their components' relationships, rather than upon the individual properties of them. While the laws of physics are still true and valid across many scales because all existing entities are in fact physically composed, other laws and regularities (also called "real patterns" or "universalities") emerge with the development of new organisational structures and states of matter which, sometimes, are insensitive to microscopic constraints. Therefore, emergence and emergentism, do not just describe some atypical processes in nature, nor the way in which we (don't) know and (cannot) explain reality. They suggest, by contrast, that the structure of the world itself is intrinsically differentiated, and that at each scale and organisational layer may correspond peculiar "emergent" phenomena exhibiting features absent at the lower or higher scales. Eventually, this ontological scale relative discontinuity may be the real cause of our scale-relative epistemology, grounding, therefore, the autonomy of the special sciences.

## Guido Bacciagaluppi, University of Utrecht, Associate Professor

### Causation as Emergent Phenomenon: A case study

This talk explores the (rather Humean) idea that causation is nothing but a certain kind of emergent pattern of correlations, perhaps specifically at a higher, phenomenological level of description. Such a case can perhaps be made already analysing the relation between classical statistical mechanics and thermodynamics, but an especially interesting case study is provided by hidden variables theories in quantum mechanics, where there seem to be problems of principle with the standard criteria for identifying causal relations (e.g. the results on fine-tuning by Woods and Spekkens). I shall draw in particular on recent results by Bacciagaluppi, Hermens and Leegwater on the relation between superdeterminism and signalling, in order to point out a tension between causation at the phenomenological level and causation at the fundamental level. Specifically, our recent work takes the well-understood result from de Broglie-Bohm theory in which in cases of 'sub-quantum disequilibrium' there is (macroscopic) signalling across EPR pairs, and extends it also to any hidden variables theory that might violate so-called measurement independence (or settings-source independence), i.e. one in which the distribution of hidden variables is not independent of the (later) measurement settings. Thus, at the phenomenological level one has a case in which Alice can signal to Bob, which is a clear case of (high-level) causation. However, assuming there is such a thing as causation at the fundamental level, the fundamental causal picture associated with such hidden variables theories does not necessarily include causation from Alice to Bob. Indeed, while in a retrocausal theory one can have causation fro Alice back to the source an on to Bob, in a superdeterminist theory causation is supposed to be fundamentally always time-like and future-directed. Thus the high-level causation from Alice to Bob must be seen as emergent.

## Joseph Kouneiher , University of Nice, Professor

### Cohomology and the Emergence Phenomenon

Much of the scientific activity is based on the idea of reducing the complex to the simple. An approach that has proven effective in many areas, but it reaches its limits in many others.

Indeed, some systems called emergent or complex have collective properties that are not reducible to those of their constitutive elements and call upon new approaches, other than those based on the notion of reduction.

The aim of this prsentation is to try to understand the phenomenon like emergence using a mathematical approach, more precisely the cohomological theories.

For instance, in the case of a manifolds, wich are a sort of complicated surfaces glued together from elementary pieces, new topological and geometrical properties occur. These properties can be detected and described by cohomology. For example in knot theory the knottedness is a global property which have no meaning locally, the twist property of Moebius band etc...

In this presentation w'll discuss some aspects of systems science, explore the different aspects of emergence as deduction, laws and explanation and discuss some philosophical implications of this new science.

## Joshua Rosaler, RWTH Aachen University, Postdoc

### Compound Reduction, Emergence, and Overlapping State Space Domains

This talk examines one sense of the term "reduction," as the relationship according to which one physical theory encompasses the domain of empirical validity of another, and considers its relationship to various notions of emergence.

The first part of the talk illustrates a particular methodology for chaining together distinct reductions, and particular consistency requirement between distinct "reduction paths" - i.e., distinct sequences of intermediate models that serve to establish a link between the reduced and reducing models. In doing so, I consider the methodology of composing reductions based on the Bronstein cube; building on the arguments of Butterfield, Hossenfelder, and others, I underscore several flaws in this methodology and the particular manner in which it employs limiting relations as a tool for effecting reduction. An alternative methodology, based on a certain simple geometrical relationship between distinct state space models of the same physical system, is then described and illustrated with examples. Within this approach, it is shown how and under what conditions inter-model reductions involving distinct model pairs can be composed or chained together to yield a direct reduction between theoretically remote descriptions of the same system. Building on this analysis, we consider cases in which a single reduction between two models may be effected via distinct composite reductions differing in their intermediate layer of description, and motivate a set of formal consistency requirements on the mappings between model state spaces and on the subsets of the model state spaces that characterize such reductions. These constraints are explicitly shown to hold in the reduction of a non-relativistic classical model to a model of relativistic quantum mechanics, which may be effected via distinct composite reductions in which the intermediate layer of description is either a model of non-relativistic quantum mechanics or of relativistic classical mechanics. Some brief speculations are offered as to whether and how this sort of consistency requirement between distinct composite reductions might serve to constrain the relationship that any unification of the Standard Model with general relativity must bear to these theories.

After defending these methodological claims about reduction, it is argued that this concept of and approach to reduction are consistent with notions of emergence based on multiple realization and the robustness of high-level regularities against alterations in the details of the underlying low-level description. In particular, the talk aims to show how the role of limiting relations in demonstrating autonomy of high-level descriptions can be reconciled with the above approach to reduction.

A copy of the associated paper can be found at: https://arxiv.org/abs/1810.02611

## Katie Robertson, University of Birmingham/Cambridge, Postdoc

### The emergence of time-asymmetry

Butterfield's criterion of emergence is that: a phenomenon is emergent if it displays novel and robust behaviour with respect to some comparison class (Butterfield 2011). In this talk, I apply this criterion to a case study in statistical mechanics. Whilst the underlying micro-dynamics (of classical, or quantum, mechanics) are time-reversal invariant, the processes described by statistical mechanics are not, in other words: they are irreversible. The archetypal example is the spontaneous approach to equilibrium of an ideal gas, as described by the Boltzmann equation. I show how this irreversibility in statistical mechanics emerges out of the underlying reversibility by explicating – and defending – a coarse-graining framework that I term the Zeh-Zwanzig-Wallace framework.

This framework takes a probability distribution evolving under Liouvillean dynamics, and coarse-grains it – throwing away certain bits of information. For example, in the case of the construction of the Boltzmann equation, information about three or more particle correlations is thrown away. To find a higher-level irreversible statistical mechanical equation, an initial state assumption and a Markovian approximation are required. If these conditions are fulfilled, then we can find an autonomous equation which does not depend on the lower-level details, which we have abstracted away from by coarse-graining. In the literature, coarse-graining is often tied to our epistemic limitations, which leads to worries that the resulting time-asymmetry is subjective. I give an alternative justification of coarse-graining, which leads to a more objective understanding of this emergent time-asymmetry.

Not only is this case study an example of emergence, but it also a case of inter-theoretic reduction: the equations of one theory, statistical mechanics, are constructed from the equations of another, classical mechanics. I claim that this suffices for reduction. Butterfield shows that his account of emergence is compatible with reduction, but in the second half of this talk I go further: I suggest that emergence often goes hand-in-hand with a particular type of reduction.

In what follows, (i) I connect reduction to the robustness criterion. I then (ii) distinguish between two types of reduction (which are a difference in degree, rather than kind) – and I claim that one of these types of reduction is closely connected to emergence, as it ensures that the novelty criterion is fulfilled.

(i) The details of Tt's reduction allow us to assess to what extent Butterfield's robustness criterion is fulfilled. Drawing on the statistical mechanical case study, I show that a phenomenon might be robust in some ways, but not in others. Some details can be thrown away by coarse-graining – but some details are crucial.

(ii) Next I distinguish two types of reduction, the first of which I term 'vertical reduction'. If the higher-level theory Tt describes a different subject matter to its underlying reductive basis Tb, then even if Tt is reduced, the phenomena it describes will be novel compared to the class of phenomena that Tb describes. Thus, the novelty criterion for emergence is fulfilled. This is clearly demonstrated by the statistical mechanical case study: the irreversible behaviour is novel with respect to the underlying time-reversible behaviour. For cases of vertical reduction, I claim that emergence will be prevalent.

But I submit that not all cases of reduction are of this vertical type. Instead of Tt describing a different subject matter, sometimes Tt describes a similar subject matter to Tb, which is the successor theory. One example of such a pair of theories is Newtonian mechanics and Special relativity. The label for this type of reduction is 'horizontal reduction'. I claim that thermodynamics does not have a significantly different subject matter to statistical mechanics. I set aside the controversial case of phase transitions and claim that, contra some authors, thermodynamics does not qualify as 'emerging' from statistical mechanics on Butterfield's account, since there is no novel behaviour, or phenomena.

## Kohei Morita, University of Kyoto, PhD student

### Model-relative emergence in physics

Many philosophers have analyzed emergence in terms of novelty and robustness (Nagel 1961; Kim 1999; Butterfield 2011; Morrison 2015; Humphreys 2016). These two notions call for further clarification, however. In this talk, I will appeal to relationships between models of higher and lower-level theories to analyze novelty as the existence of properties that cannot be derived from lower-level models (inderivability condition), and robustness as the independence higher-level models from differences in lower-level models. Focusing on relationships between models (as opposed to theories) is beneficial for analysing not only reduction, as Rosaler (2016) convincingly argues, but also emergence in physics.

I will focus on Renormalization Groups (RG) in the case of phase transitions to illustrate my analysis of novelty and robustness. Consider an RG analysis of e.g., a spin lattice as an example of a system undergoing phase-transition. This analysis examines a model of physical systems exhibiting phase-transitions. Such models have been usefully characterized as "minimal models" by Batterman and Rice (2014). In minimal models, several properties which cannot be derived from each models of particular target systems can appear. This is the novelty characterizing the emergence. And a minimal model can explain a property exhibited by several different kinds of, indicating how various detailed differences do not matter. To some extent differences in the initial conditions of the target systems do not prevent us from deriving the properties in the minimal model. This characteristic (a sort of independence) can be called as robustness.

In order to explicate the characterization of novelty and robustness in terms of minimal models, it is helpful to compare with other kind of models that can be called as general models. The general model does satisfy the robustness condition, but not inderivability conditions. Consider the Lotka-Volterra model. Admittedly this is not case from physics, but in the context of philosophy of scientific models this example has been examined (ex. Weisberg 2013) and it can clarify inderivability. This model can give an account for the time development of the relationships between preys and predators in general (for instance, the numbers of sharks and fish in the sea). This model can explain several kinds of systems, and therefore it satisfies the condition of robustness. On the other hand, it cannot show the novelty with respect of the properties exhibited in particular target systems. The pattern of periodical changes of the numbers of prey and predators that Lotka-Volterra model can demonstrate can be found in the models of each particular target systems. This case shows that the properties in general model can be derived from the particular models of the target systems. In the end, this case does not satisfy the condition of inderivability.

Comparing the minimal model and general model, the meaning of inderivability can be grasped. The connections between the general or minimal models and these target systems will exhibit significant differences between these two types of models in terms of their inderivability. In the case of the Lotka-Volterra model, the details of the target systems can give more accurate representations of the behaviors of it. On the other hand, in the case of the minimal model, especially in the case of RG, the details of the target system rather prevent an explanation of properties which the minimal model could explain without the details. This difference well illustrates that the inderivability in the minimal models does not come from lack of information about the details.

On the other hand, the condition of the robustness is satisfied in both case. But no one argues that Lotka-Volterra model exhibits emergence in the same sense as RG does. In this sense, robustness alone does not define emergence. But even if such non emergence model can satisfy the condition of robustness, this does not mean this condition can be discarded. My strategy depends on comparing models one of which represent many targets as a whole and the other one of which represents several particular target systems. What if these two models do not share any target systems? In this case, the conditions of inderivability is easily satisfied. For instance, some behavior exhibited in a model of economics cannot be derived from a model of chemistry. However, such a trivial case should be excluded. Thus, it is an important condition that these two models share the same target systems. The robustness condition, such that one model can give an account of the behaviors of several kinds of target systems does include this condition of sharing the target systems.

In sum, emergence is characterized by novelty understood as inderivability and robustness as independence. Precisely, there is emergence if one model exhibits novelty and robustness in relation to another model which shares the same target systems. Comparing the models enables to us to characterize this idea.

## Marta Conti , King's College London, Master student

### Is weak ontological emergence an unstable view?

The aim of this talk is to assess Jessica Wilson's weak ontological emergence, which is a formidable attempt to answer the question of how higher-level properties (in particular, mental properties) may be causally efficacious within a physicalist framework.

In the late seventies Smart and Feigl's type identity theories faced different challenges that undermined their popularity, Kripke's modal argument and Putnam's multiple realization argument being the most prominent. However, there was not a resurgence of dualism. Philosophers of mind mainly rejected reductionism while maintaining physicalism (Kim, 1993a: 266). On the one hand, eliminativists claimed that the failure of type identity theories entailed that mental states do not exist. On the other hand, nonreductive physicalists argued that the failure of type identity theories was due to the fact that mental states have an irreducible nature. This latter approach is similar to the one held by emergentists in the first half of the twentieth century. In fact, Kim argues that nonreductive physicalism is a kind of emergentism (Kim, 1992: 128, 1993b: 344), and uses this identification to undermine nonreductive physicalism. But what is emergentism?

According to Kim, emergentism is a middle path between physicalist reductionism and Cartesian dualism. On the one hand, emergentists are physicalists because they claim that there is nothing over and above fundamental physical entities - they are the building bricks of everything that exists. On the other hand, emergentists are nonreductionists because they claim that, in some cases, when fundamental physical entities are assembled in complex ways they bring about novel properties. These novel properties cannot be predicted nor explained at the low-level of their constituents. Thus, these novel properties are not epistemically reducible to their constituents. (Kim, 1999: 5). However, if we want higher-level emergent properties to be ontologically robust, epistemic irreducibility may not be enough. As Alexander claimed: "to be real is to have causal powers" (Kim, 1993b: 348). Hence, according to this view, if emergent properties are to be ontologically robust and not mere epiphenomena, they must bestow new causal powers.

As I mentioned above, Kim explicitly identifies emergentism with nonreductive physicalism. According to this view allegedly shared by emergentists and nonreductive physicalists, mental properties are higher-level properties causally autonomous (by having new causal powers) and synchronically dependent on lower-level neurophysiological entities.

Once Kim has identified emergentism with nonreductive physicalism he can use his famous causal exclusion argument against both views. The argument can be found in several of Kim's papers, such as Kim (1993a, 1999, 2006), and its main strategy is to show that nonreductive physicalism is an unstable view because it embraces five claims that give rise to a contradiction. The first two are claims that no physicalist would deny, and the following three are the core claims of nonreductionism.

(1) Physical Causal Closure, which claims that for every physical effect there is a sufficient physical cause (2) the Non-overdetermination Principle, which asserts that physical effects are not systematically overdetermined by two or more independent and sufficient causes (this definition excludes double-rock-throw cases and causal chains) (3) mental properties depend on their base properties (4) mental properties are causally autonomous from their base properties (5) mental properties are distinct from their base features

Suppose that M is a mental property in the L level that causes feature P* in the lower-level L-1. Given Physical Causal Closure, P* has a physical cause. Say that M's physical base is P and P is a sufficient cause for P*. Both P and M cause P*, and given that they are distinct and causally autonomous, there is a denial of Non-overdetermination in every case of downward causation. In order to avoid the violation of Non-overdetermination one must reject one of the causes. Provided that Physical Causal Closure holds, every case of downward causation can be accounted for in terms of basal properties. Hence, higher-level causes are the ones to be rejected. For this reason this argument is called by Kim the causal exclusion argument, because its outcome is that lower-level causes exclude higher-level causes (Kim, 2006: 558). From Kim's stance the only way to be causally efficacious is to have a new causal power. This is the reason why Kim (1993a) argues that nonreductive physicalism is unstable and collapses either into strong emergentism or reductive physicalism.

Jessica Wilson's nonreductive physicalist theory (weak ontological emergentism) is designed to avoid the causal exclusion argument. Wilson claims that nonreductive physicalism is a kind of emergentism but denies that the main trait of emergent properties is to bestow new causal powers. A mental emergent property may be causally autonomous and efficacious by having a distinct causal profile than its physical base. Firstly, given that Wilson talk of causes is in terms of causal powers, I shall present a powers-based version of Kim's exclusion argument. Secondly, I shall characterise Wilson's nonreductive physicalism and how it is able to circumvent the new powers-based formulation of Kim's argument. Finally, I shall discuss whether Wilson's theory is really a nonreductionist theory by presenting Sara Bernstein forthcoming paper. The central tension of the nonreductive physicalist's view set in Bernstein paper is no other than Kim's (1993a, 1993b) claim that nonreductive physicalism is an unstable view that collapses either into reductive physicalism or strong emergentism. This is because, as Kim, Bernstein considers that the mental can be efficacious qua mental only if it bestows different causal powers. In order to defend Wilson's theory I shall discuss the commonalities of Bernstein and Kim's critiques and whether the answer provided by Wilson to Kim's threat is able to deal with the objections raised by Bernstein.

## Nuria Munoz Gargante, Max Planck Institute for History of Science, PhD student

### The Icon of Emergence, Revisited

The concept of emergence is certainly having a great impact on the philosophical community and is opening new doors of communication between philosophers of science and the science practitioners. This is notable in the case of physics, in which emergence is being very seriously taken into consideration as a new epistemological tool for a whole range of phenomena, especially involving symmetry breaking and renormalization. The interest of physicists in this concept has surely influenced the philosophical debates on emergence, providing new case studies —such as phase transitions, see Batterman (2001)— that are enriching the understanding and the taxonomy of such concept. Unfortunately, this influence is not always bilateral and physicists' definitions of emergence still lack the philosophical clarity that one would desire. My question is: how safe is to interpret the physicists' concept of emergence as a philosophically coherent concept?

More specifically, I will focus on the figure of Philip W. Anderson, a Nobel laureate physicist with an active trajectory in the field of condensed matter physics of more than 50 years. The first, more superficial, reason to chose him as the central figure of my work is that he symbolises emergence in physics, as he is considered to be the one "who first introduced the phrase 'emergent phenomenon' into physics", in Piers Coleman words (Coleman, 2015). However, going further, one realises that his relationship with emergence was not one of "love at first sight" and furthermore, he was not the first physicist to talk about emergent phenomena — see Polanyi (1958). So there is a deeper interest in starting this study around the figure of Anderson, not so much to perpetuate the common narrative, but to enrich it in order to avoid the simplistic view that Anderson magically introduced the philosophy of emergence in the physicists mindset.

The starting motivation for this work in progress was the realisation that Anderson doesn't mention the concept of emergence in his iconic article "More Is Different" (Anderson, 1972). The main reason is that he didn't knew about the concept back then, as he points out in the introduction of a book on the history of condensed matter physics (Ong and Bhatt, 2001): " 'Emergence' was a term from evolutionary biology with which I, like most physicist, was unfamiliar at that time." However, an interesting fact is that Anderson's concept of emergence is mostly associated uniquely with this article MID. Here my question arises: To what extent can we interpret Anderson's concept of emergence based on "More Is Different"? I will argue that it is misleading to project into MID a philosophy that he only acquired later. The aim is not to take the status of icon of emergence away from Anderson, but to offer historical facts on how he came across the term, what he first thought of it and how he developed it through the years. This will support the thesis that it is very difficult to arrogate one definite position on "emergence" to Anderson, contrary to many attempts which result in very different kinds of interpretations, from anti-fundamentalist (Cartwright, 1999), to ontological emergentist (Schweber, 1993) or making metaphysical claims (Mainwood, 2006), among others. This is important in order to hopefully provide a more accurate understanding of the reception, usage and proliferation of the concept of emergence within physics and its relation with other disciplines in which emergence is also discussed, since Anderson has clearly been a source of inspiration for many.

## Olivier Sartenaer, University of Cologne, Postdoc

### Emergence without Hierarchy

When British emergentists initially appealed to the concept of emergence in the early 20th century, they aimed at laying the groundwork of a philosophy of nature that was supposed to constitute a middle course between two antagonistic worldviews, namely - and in a knowingly anachronistic phrasing - reductive physicalism and substance dualism. Emergence, as a relation between an 'emergent' and its 'emergence basis', was indeed to be construed from the very start as a conjunction of two demands. First - call this the 'dependence demand', which is in tension with dualism -, emergents were thought to somehow depend on their bases. Second - this is the 'distinctness demand', which prima facie conflicts with physicalism -, emergents were also to be considered as distinct from their bases. From the outset, emergence was given an ontological guise. It was put at the service of an overall view of the natural world that contains things which, though ultimately dependent on a common and unifying physical basis, are also genuinely distinct from it.

Although emergentism initially intended to resolve the secular conflict between physicalism and dualism, it is somewhat ironic that, today, an avatar of this conflict inexorably remains within emergentism itself. Far from constituting the originally targeted mediating middle course, contemporary emergentism is indeed fragmented in a strongly polarized variety of emergentisms, some of them giving the upper hand to dependence at the expense of distinctness - hence coming close to reductive physicalism -, some favouring distinctness over dependence - hence verging rather on substance dualism (or, more generally, substance pluralism). Between both these opposite trends, and mirroring the pre-emergentism situation, it seems that no conciliatory middle course is to be found. This led some philosophers to adopt a deflationary stance with respect to the initial pretence of emergentism: in no way could one ever coherently 'have the cake and eat it too' (Kim 2005). Emergentism appears to come with a false promise indeed. Reductive physicalism and substance dualism are the only cards on the table.

Although there is some truth to this story, for there actually is something of a community conflict within contemporary emergentism, opposing proponents of reduction-friendly emergence to advocates of dualistically-inclined emergence, some recent developments turn out to mitigate this relatively cynical overview of the current state of play. Some philosophers have indeed recently paved the way to genuine forms of ontologically non-reductive physicalism, in the spirit of the original conciliatory promise of emergence (see e.g. Gillett 2016). While it is still an open question whether these approaches are successful in this respect, they certainly crystallize the hope, one century after the initial rise of emergentism, of finally rendering physicalism hospitable to an authentic worldly diversity.

The main contention of the present talk is that these current approaches, though potentially fruitful in their own way, are not comprehensive, in that they share a common bias that make them blind to some conceptual space available to ontological emergence and, accordingly, to some clear-cut empirical cases of such an emergence. As I will endeavour to show, the bias in question is twofold. It consists in considering whatever emerges to be both systematically simultaneous with, as well as belonging to a higher level with respect to, what it emerges from. In other words, it is about postulating that the emergence relation essentially is both synchronic and hierarchical. What I aim at showing in this talk is that putting aside such a twofold postulate allows for devising and exploring the prospects of an alternative perspective on ontological emergence, referred to as 'diachronic and flat emergence' or, to put it simply, 'flat emergence'. More particularly, I argue that sketching a theory of such an emergence is relevant in two respects: one conceptual, the other empirical. Not only does flat emergence constitute another viable way to dissolve the current community conflict and fulfill the initial emergentist promise, but it also allows for making sense of some emergence ascriptions that synchronic and/or hierarchical accounts are unable to accommodate.

Here is how the talk will be structured. First, I will provide a general sketch of flat emergence and justify the claim that it is a bona fide variety of the notion. I'll then go on to show that flat emergence is a generalization of some recent accounts of diachronic emergence, among which Humphreys' (2016) and Guay and Sartenaer's (2016) "transformational emergence". On this basis, I will highlight some notable features of flat emergence related to holism, fundamentality, unexplainability and bruteness, focusing incidentally on the fact that it vindicates a form of supervenient irreducible causation that is immune to Kim's causal exclusion argument. Finally, I'll turn to a comparison of flat emergence with some of its traditional distant cousins, including O'Connor and Wong's (2005) "diachronic emergence" and Wilson's (2015) "weak" and "strong" emergences.

## Quentin Rodriguez, Universite Clermont Auvergne, PhD student

### Emergent explanations for critical phenomena: a matter of analogies?

Over the last decades, many statistical and condensed matter physicists have claimed that the use of renormalization methods to explain "universality" in critical phenomena provides a genuinely new kind of explanation in physics: in this view, explanation no longer concerns physical quantities and constituents' properties, but "exponents" and "collective properties". As Nigel Goldenfeld put it, "a new way of looking at physics emerged" (Goldenfeld 1992, p. 16).

Some philosophers of science have seen these explanations of "universality" as an evidence for emergent phenomena within the realm of physics, because of the essential use of infinite idealizations or "singular limits" (Batterman 2002, Chibbaro, Rondoni and Vulpiani 2014, Morrison 2015). Others have argued that these infinite idealizations could be eliminated, i.e. understood as "mere" approximations (Norton 2012), ending up in a reductive account of critical phenomena (Palacios, forth.).

In order to understand the precise meaning of an "emergent universality" in critical phenomena, I will argue that we need to identify carefully what distinguish these explanations from other explanatory unifications using infinite idealizations that we do not consider as emergent. To this end, I will compare the way to produce explanatory unification using renormalization methods with the one taking place with (1) the ideal gas model, and (2) the harmonic oscillator model. The first case is the most well-known example of successful reduction in thermodynamics, and I will take the second one as an example of explanatory unification neutral towards reduction or emergence.

Comparing these three cases of explanation, I will endorse what I think is the most important intuition of Batterman: if we spell out the difference between reduction and explanation, then we can make room for positively emergent explanations, as in the case of universality in critical phenomena. In the same time, I will agree with Norton or Palacios about the possibility to eliminate infinite idealizations in critical phenomena. However, I will draw attention to the way different analogies support the explanatory power of these models and their idealizations: a physical one in the case of the ideal gas model, and a formal one (Hesse 1966) in the case of the harmonic oscillator model. Finally, we will see how in the case of critical phenomena a specific interplay between physical and formal analogies may give birth to an explanatory autonomy strictly tied to the infinite idealizations used. Far from contradicting any reductive account of a specific phenomenon, this explanatory autonomy allows us to add more comprehensive emergent explanations.

## Samuel Fletcher, University of Minnesota, Twin Cities, Assistant Professor

### Similarity Structure and Emergent Properties

Recent influential work by Butterfield (2011a,b) has renewed interest in how the concept of emergence is implemented within modern physics: the concept is widely invoked, rarely defined, and even when it is, it is typically only informally. Butterfield himself goes some way to illustrate this implementation (and its relation with concepts of reduction and supervenience) in various cases from physics, but does not provide a completely explicit definition. Thus the adjudication of his cases, and further ones, has continued to rely on informal intuitions and ostensive comparisons with purportedly intersubjectively agreed upon cases.

The goal of the present project, by contrast, is to provide precise formal definitions of emergence concepts as they apply to sufficiently mathematically formalized scientific theories—although the applications and examples I discuss at the end are from physics, my definitions could extend to any theories or approaches whose (mathematical) models are specified precisely. The chief formal innovation I employ is similarity structure, which consists in a structured set of similarity relations amongst those models under analysis—and their properties—and is a generalization of topological structure. A fixed similarity structure does not accrue to a theory once and for all, I argue, but must be adapted to the application of the theory in a particular investigative context: it should encode all and only the properties amongst models that make a difference to the context. Because this can vary over time and between researchers according to what scientists can and have measured, and how and what they take the models in questions to represent, whether a property is emergent depends as well on these factors, which are not a part of the theory or its formalism themselves. So, even though the definitions of emergence I provide are formal, they require input from outside the formalism itself.

Before going into more detail, a few qualifications are in order. First, as O'Connor and Wong (2015) aptly remark, "Emergence is a notorious philosophical term of art," one with a variety of conflicting usages and definitions. The sort of emergence of concern here is that of one or more properties of a system or state of affairs, as described by one theory, from that provided by another theory. Whether this is metaphysical or merely epistemological emergence will depend on whether one's (contextually appropriate) attitude toward the theories in question is more realist or anti-realist, but that question can be set aside for present purposes, as its answer does not substantively affect the formal features of the analysis. Further, the notion of emergence here is synchronic: it will describe the relationships of models of theories and novel properties thereof, not how properties of systems or states of affairs arise in time.

Informally, on the present account, a property of a model is emergent with respect to another class of models just when it is comparatively novel (Butterfield 2011a,b). (Butterfield also sometimes suggests that emergence properties must also be "robust," but does not explain why; indeed, in later expositions (Butterfield 2014) this requirement is dropped.) This novelty can come in different sorts, so I distinguish four different types of emergence partially ordered in strength. The weakest, weak emergence, requires only mere non-identity of the property—or the value of that property, if it is not a simple predicative property—of the model with any of the properties of the models in the comparison class. (Philosophers are most familiar with predicative properties—those that obtain or not—but modern physics treats more complex properties, which can be real- or vector-values, for instance.)

One might require not just mere non-identity, though, but a sort of unexpectedness or comparative unexplicability. This can be formalized along at least two directions. The strong emergence of a property of a model requires that the property must also be not sufficiently similar to the properties of the models of the comparison class—it is unexpected because it is not even similar (in the relevant ways) to the properties available for consideration from the comparison class. This requires similarity structure on the space of values that a property can take on. The non-reductive emergence of a property of a model requires that the property must also be non-identical with the corresponding properties of the models arbitrarily similar to those in the comparison class. This requires similarity structure on the joint collection of models. Finally, radical emergence is just the conjunction of strong and nonreductive emergence. Accordingly, this requires similarity structure on both the space of values that a property can take on and the joint collection of models themselves. All of these concepts readily generalize from applying only to properties of individual models to the properties of sets of models.

Contrary to common usage, two of these concepts of emergence—the weak and strong varieties—will not only be compatible with a type of intertheoretic reduction, as Butterfield (2011b) has forcefully argued, but will often be a consequence of it (although not when reduction is understood narrowly as deduction, pace Butterfield). Indeed, I formulate and prove some propositions to this effect, illustrating with the example of general relativity and Newtonian gravitation, arguing that absolute simultaneity is an emergent property in models of the latter.

## Sander Beckers , University of Utrecht, Postdoc

### Abstracting Causal Models

We can and typically do analyze problems at different levels of abstraction. For example, we can try to understand human behavior by thinking at the level of neurons firing in the brain or at the level of beliefs, desires, and intentions. A political scientist might try to understand an election in terms of individual voters or in terms of the behavior of groups such as midwestern blue-collar workers. Since, in these analyses, we are typically interested in the causal connections between variables, it seems reasonable to model the various levels of abstraction using causal models (Halpern 2016; Pearl 2000). The question then arises whether a high-level “macro” causal model (e.g., one that considers beliefs, desires, and intentions) is a faithful abstraction of a low-level “micro” model (e.g., one that describes things at the neuronal level). What should this even mean?

Perhaps the most common way to approach the question of abstraction is to cluster “micro-variables” in the low-level model into a single “macro-variable” in the high-level model (Chalupka, Eberhardt, and Perona 2015; 2016; Iwasaki and Simon 1994). Of course, one has to be careful to do this in a way that preserves the causal relationships in the low-level model. For example, we do not want to cluster variables X, Y, and Z into a single variable $X + Y + Z$ if different settings $(x, y, z)$ and $(x', y', z')$ such that $x + y + z = x' + y' + z'$ lead to different outcomes. Rubenstein et al. (2017) (RW+ from now on) provided an arguably more general approach to abstraction. They defined a notion of an exact transformation between two causal models. They suggest that if there is an exact transformation $\tau$ from causal model M1 to M2, then we should think of M2 as an abstraction of M1, so that M2 is the high-level model and M1 is the low-level model.

Abstraction almost by definition involves ignoring inessential differences. So it seems that RW+ would want to claim that if there exists an exact transformation from M1 and M2, then M2 and M1 are the same, except for "inessential differences". This leads to the obvious question: what counts as an inessential difference? Of course, this is to some extent in the eye of the beholder, and may well depend on the application. Nevertheless we claim that the notion of "inessential difference" implicitly encoded in the definition of exact transformation is far too broad. As we show by example, there are models that we would view as significantly different that are related by exact transformations. There are two reasons for this. The first is that, because RW+ consider probabilistic causal models, some differences that are intuitively significant are overlooked by considering just the right distributions. Second, because RW+ focus only on a possibly small set of allowed interventions, differences that are apparent when considering other possible interventions are overlooked as well.

In this paper, we consider a sequence of definitions of abstraction, starting with the RW+ notion of exact transformation, moving to a notion of uniform transformation that applies to deterministic causal models and does not allow differences to be hidden by the "right" choice of distribu- tion, and then to a notion that we call abstraction, which takes more seriously all potential interventions in a model, not just the allowed interventions. As we show, procedures for combining micro-variables into macro-variables are instances of abstraction, as are all the examples considered by RW+.

## Simon Friederich, University of Groningen, Assistant Professor

### Observers in cosmology as emergent and the problem of testing multiverse theories

The assumption that we are /typical/observers plays a core role in attempts to make multiverse theories empirically testable. A widely shared worry about this assumption is that it suffers from systematic ambiguity concerning the reference class of observers with respect to which typicality is assumed. As a way out, Srednicki and Hartle recommend that we empirically test typicality with respect to different candidate reference classes in analogy to how we test physical theories. Unfortunately, this idea fails because typicality is not the kind of assumption that can be subjected to empirical tests. As an alternative, a /background information constraint/on observer reference class choice is suggested according to which the observer reference class should be chosen such that it includes precisely those observers who one could possibly be, given ones assumed background Information.

Based on this formal solution to the observer reference class problem, I discuss the prospects for subjecting multiverse theories to rigorous empirical tests and come to a pessimistic conclusion. The most severe problem is that observers are emergent entities that have no rigorous physical characterization. Researchers using the background information constraint must in practice make pragmatic choices concerning an observer proxy and, in the context of eternal inflation, a cosmic measure to make multiverse theories testable. We can expect researchers to consciously or unconsciously become victims of confirmation bias and exploit thoses choices to arrive at findings compatible with their preferred multiverse frameworks, thus undermining the credibility of any claimed successful tests of concrete multiverse theories.

## Thomas Durlacher, University of Luxembourg, PhD student

### Weak emergence, computer simulations and complex systems

This paper explores the notion of weak emergence and the question how computer simulations are able to help us understand emergent phenomena in the natural and social sciences. Several case studies of computer simulations intended to represent emergent behavior ranging from cellular automata to agent-based models will be presented. With the help of these case studies, I am going to explicate the notion of weak emergence originally coined by Mark Bedau and answer the question how the method of simulating phenomena on a digital computer informs the notion of weak emergence. Weak emergence is commonly identified with an anti-reductionist position towards high-level phenomena. (Gillett 2016) Bedau defined weak emergence in two ways, both of them closely related to computer simulations. He argues that macro-phenomena are weakly emergent if and only if they can be derived from the initial micro-state of the system but only by way of simulation. (Bedau 1997) In his second definition of weak emergence, a phenomenon is weakly emergent if and only if it can be generatively explained but in a non-compressible way. By arguing that weakly emergent phenomena are explanatorily incompressible Bedau wants to emphasize that the only way to represent these phenomena is to 'crawl the causal web' and that there is no easy shortcut to predict the behavior of the system. (Bedau 2007) In this way this second definition is still largely dependent on computer simulations because in many or all cases only computer simulations have the computational power to mimic the process that leads to the emergent phenomena step by step.

This close relation between a certain scientific method, namely computer simulations, and a metaphysical category like emergence raises the question if weak emergence depicts a genuine property of nature or is epistemological in character. If the epistemological interpretation is correct the incompressibility stems from our limited abilities to understand the phenomena we are interested in or even in our limited ability to understand the computer simulations themselves. According to this interpretation the weakly emergent phenomena show no new properties, but are rather unexpected and therefore only give the impression of genuine emergence. Although the system showing weakly emergent properties cannot be reduced in practice it could be reduced in principle a question which, for Bedau, has to be decided empirically. For him weak emergence is a feature in the world and at the same time metaphysically innocent because it does not introduce novel properties at a higher level of the system. The same is true for the question of causal powers. Weakly emergent phenomena have no causal powers over and above the micro-entities that underlie the system. Another property often associated with weakly emergent phenomena is their diachronic character. This shifts the focus from the question how macro and micro properties relate to each other to the question how the system under consideration evolves over time. (Humphreys 2016)

Bedau's version has been very influential in the area of complex system research where computer simulations are routinely used to explore the properties of complex systems. Different types of examples from this area are shown to exemplify the relationship between computer simulations and weak emergence. These include flocking and swarm behavior, traffic jams, social networks and different kinds of simulation methods like cellular automata, agent-based and equation based-computer simulations.

## Tiziano Ferrando , King's College London, PhD student

### Emergent patterns

Ladyman and Ross (2007, 2013) propose an ontology of real patterns based on preliminary work by Dennett (1991) and Ross (2004). Real patterns are supposed to give a precise way of understanding what emergence is and the relation between fundamental physics and special sciences. I argue that although the theory is tenable, it stands in need of elaboration with respect to some relevant issues: (1) Clarify the relation between the three existing approaches to describe real patterns: information-theoretic, statistic, and dynamic; (2) Establish the mind-independence of real patterns; (3) Introduce a notion of ontological dependence between emergent entities; (4) Give an account of scale relativity that incorporates ways emergence occurs at scales others than size or time, particularly with respect to energy and complexity. The aim of the paper is to address these issues:

(1) I argue that the information-theoretic definition of real patterns in Ross (2004) and Ladyman and Ross (2007) subsumes the ones in terms of non-redundant statistics and reduction of degrees of freedom, although depending on the context it may be useful to use one or the other. This is because in the end all three rely on information-processing, whether we are looking for statistical generalisations or the dynamics of a system in phase space. The information-theoretic setting may nevertheless be flawed as it stands, as suggested by Beni (2017)'s criticism of the notion of projectibility.

(2) The ontological status of patterns and their connection to pattern-recognisers (agents, observers or information processors) can be understood as the manifestation of a power. Potential patterns manifest themselves as information when a system is coupled with a pattern-recogniser. Through the introduction of powers, we can say that the pattern can convey information if, at the right scale, it is coupled to a pattern-recogniser with enough computational resources. If there is no pattern-recogniser the pattern exists as unmanifested. This way we could say that although real patterns are indeed a product of data compression, there are patterns when no one looks at them. Also, this way of conceiving of "patterns in the wild" as potentialities may fit well with a proposal by McAllister (2011), who claims that each data set admits all possible patterns with a different amount of noise, and that the presence of a pattern when confronting datasets points to an existing structure in the outside world. The emergent and irreducible features of a real patterns give us new ways of addressing questions concerning identity, persistence and vagueness.

(3) Dynamics and degrees of freedom of a system play an important role in understanding how emergent patterns relate to other patterns at different scales. I grant Ladyman (2017) that an account of composition which fits actual science has to be dynamic and diachronic, and I argue that the same should hold for ontological dependence. I propose a notion of dynamical dependence for inter and intra level patterns, and explore whether it should be taken to be symmetric/asymmetric, transitive/intransitive, global/local. I argue that even if there might be no general notion that works for all cases of dependence between patterns, one could still benefit from considering dynamical dependence as an umbrella term, and address case by case the specific features of the relation according to the relative scientific domain.

(4) Ladyman and Ross (2007) claim that ontology is scale relative with respect to both space and time. I agree with the claim, but add that those are not the only scales we should look at when searching for "novel and robust behaviour" (Butterfield 2011). Interesting considerations about emergence, persistence and fundamentality are relative to the scale we are investigating. I will focus on the question of whether genuine emergence could occur

with respect to some scales but not to others. Phase transitions occur at different levels of the energy scale, but extension in space and time fails to capture the relevant dynamical dependence. Complex behaviour could also count as emergent, but the complexity scale seems to be independent from space and time: the functioning of a star is simpler than a cat's digestive system. I will consider the interplay between different scales, and whether some scales could be taken to be dependent on others or redundant.

## Vanessa Seifert, University of Bristol, PhD student

### Strong Emergence in Chemistry

I examine a position which is extensively discussed in the philosophy of chemistry literature. This position is strong emergence, as this is understood by Robin Hendry for the case of the relation between chemistry and quantum mechanics. Hendry argues that the structure of a single inert molecule strongly emerges from its quantum mechanical entities. He specifies this with reference to downward causation, according to which, 'the emergent behaviour of complex systems must be viewed as determining, but not being fully determined by, the behaviour of their constituent parts' (Hendry 2006: 180). I present Hendry's account and argue that the manner in which Hendry supports his understanding of strong emergence in terms of downward causation is problematic and that, therefore, his proposed account of strong emergence is untenable.

My paper is organised in two parts. In the first part, I present strong emergence and define downward causation (DC), as this is argued for by Hendry with respect to the relation between chemistry and quantum mechanics. Very briefly, there are three core elements that underwrite Hendry's understanding of strong emergence. These are: (i) A hierarchy of levels; (ii) the existence of a dependence relation (namely supervenience); and, (iii) the causal autonomy of the higher-level. Hendry's understanding of causal autonomy (and thus of strong emergence) is specified in terms of downward causation. That is, according to Hendry, the higher level is causally autonomous iff it exhibits downward causal powers.

In the second part, I present three objections against Hendry's account of strong emergence in terms of downward causation. Very briefly, these objections are the following. First, the empirical evidence presented for the support of downward causation equally undermines supervenience. Supervenience is one of the main tenets of Hendry's account of strong emergence. Therefore, it is important to clarify this point. Secondly, Hendry argues that making ad hoc assumptions in quantum mechanics in order to quantum mechanically describe the structure of a molecule is consistent with the view that molecular structure strongly emerges. However, the use of ad hoc assumptions is a very common practice across all sciences, including chemistry. Therefore, one needs to address why in this particular instance it is considered as an indication of strong emergence.

Thirdly, it is crucial to specify how causation is understood when referring to downward causation. Hendry does not explicitly state which notion of causation he assumes when referring to downward causation. This is a weakness of Hendry's account because there are particular understandings of causation which do not adequately support the existence of a downward causal relation. Specifically, Hendry understands downward causation as a diachronic causal relation between higher level entities at t1 and lower level entities at t2. In this context, if one understands (downward) causation in terms of nomological sufficiency, then one needs to show that:

(i) the quantum mechanical entities, etc. that specify a molecule at t1 are not nomologically sufficient for the occurrence of the quantum mechanical entities that specify that molecule at t2; and, (ii) that the higher-level entities, etc. that specify the molecule at t1 are nomologically sufficient for the occurrence of the lower-level entities, etc. that specify that molecule at t2.

By employing Ned Hall's (2004) requirements for nomological sufficiency, I argue that Hendry sufficiently supports (i), but he does not show that (ii) holds. In fact, I argue that (ii) does not hold; the chemical entities, etc. at t1 are not nomologically sufficient for the occurrence of the quantum mechanical entities at t2.

Given the above, I conclude that Hendry's account of the strong emergence of molecular structure is not tenable. However, this does not exclude the possibility that alternative accounts of emergence are tenable with respect to chemistry's relation to quantum mechanics. In light of this, the above analysis aims at contributing to the discussion of emergence both in the philosophy of science, as well as in the philosophy of chemistry.

## Manus Visser, University of Amsterdam, PhD

### Emergence of Black Holes in String Theory

This talk investigates whether black holes are emergent in a string theoretic framework. A central result in string theory is the counting of microscopic states of black holes by Andrew Strominger and Cumrun Vafa in 1996. They analysed the black hole in terms of D-branes, and derived the entropy of black holes from a statistical mechanical entropy. We first give a conceptual analysis of the Strominger-Vafa argument. Second, we assess whether the black hole should be considered as emergent from the collection of D-branes, particularly in light of the role that duality plays in the argument.

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