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QUAI 22 & ESPACE AGORA
NAMUR

CONF. Probing the prospects of emergence in phase and evolutionary transitions

REDUCTIONISM *IN* TRANSITIONS

oct 10 ESPACE AGORA
PHYSICS

Jeremy Butterfield (University of Cambridge)
Vincent Ardourel (CNRS, Université Paris 1)
Eleanor Knox (King's College London)
Patricia Palacios (University of Salzburg)
Kohei Morita (Kobe University)
Andreas Hüttemann (University of Cologne)

oct 11 QUAI 22
BIOLOGY

Samir Okasha (University of Bristol)
Johannes Martens (CNRS, Sorbonne Université)
Fridolin Gross (University of Bordeaux)
Tarja Knuuttila (University of Vienna)
Alexandre Guay (University of Louvain)
Margarida Hermida (King's College London)

8h45-10h00 – **Jeremy Butterfield** (University of Cambridge) Emergent Ontology and Structural Realism: Quantities as Objects and Objects as Quantities

I argue that physics' endemic practice of solving problems by defining appropriate quantities suggests a natural formulation of two philosophical doctrines, viz. (i) the claim that the objects of the special sciences (and of everyday life) are patterns, and (ii) ontic structural realism. For physics' focus on its appropriate quantities suggests treating quantities as objects: which gives a formulation of the idea of objects as patterns. And it also suggests treating objects as quantities: which gives a formulation of ontic structural realism. I develop these proposals and give some examples from physics. My discussion owes much to work by David Wallace.

10h00-10h45 – **Vincent Ardourel** (CNRS, Université Paris 1 Panthéon-Sorbonne) Singular Limit, Reduction, and Turbulence in Fluid Mechanics

The talk focuses on the inviscid limit $\nu \to 0$ in fluid mechanics (with ν the fluid viscosity) as a case of singular limits in physics. I discuss Michael Berry's statement: "the limit $\nu \to 0$ is singular, and out of the singularity emerges an important phenomenon, namely turbulence (…)" (1995, p. 600 with my notation). First, I analyze how the inviscid limit challenges the limiting reduction of viscous to ideal fluid mechanics. Second, I show how the transition to turbulence occurs ''before the limit'' $\nu \to 0$.

11h15-12h30 – **Eleanor Knox** (King's College London) Emergence and (Constitutive) Functionalism

This talk extends a recent distinction made between constitutive functionalism and causal-role functionalism (Knox and Wallace 2023) and examines its application to debates about reduction and emergence in physics. It proposes that many cases of emergence may be understood as cases in which ontological commitment is licensed by constitutive functionalism, but where causal-role functional reduction fails. This is not incompatible with the recent consensus that emergence is compatible with reduction – these cases involve the failure of a particular mode of reduction, and not reduction in general. Following a suggestion by Bangu (2015), I'll apply this to the case of phase transitions, and also examine the relationship between this and Wallace's real-patterns account in maths-first structural realism.

14h00-15h15 – **Patricia Palacios** (University of Salzburg) Emergence, Reduction and Critical Phase Transitions

Critical phase transitions and their characteristic universal behavior have been at the center of recent debates around reduction and emergence in physics. For some, phase transitions are a case of successful reduction, while for others they constitute the hallmark of emergence. Not so many years ago, Butterfield (2011, 2014) and Norton (2014) suggested that phase transitions combine both emergence and reduction. In this talk, I develop further this compatibilist view and argue that critical phase transitions instantiate two different notions of weak emergence that I call "few-many" and "coarse-grained" emergence. At the same time, I will contend that they are successful cases of intertheoretic reduction, understood as a family of models that can be combined in order to achieve certain epistemic and ontological goals.

15h15-16h00 – **Kohei Morita** (Kobe University) Evaluating Relationships between Models in Critical Phenomena and Superconductivity

Among phase transitions, critical phenomena and superconductivity are typical examples of emergence in physics (Morrison 2012; Bishop et al. 2022). In particular, critical phenomena are explained by the renormalization group (RG) method. This theoretical framework, which includes infinitely iterative transformations and coarse-graining procedures, shows that critical phenomena are autonomous and qualitatively novel from the model of their microscopic details. De Haro (2019) defines emergence as not only the relationship between theories but also models, and argues that the RG method implies emergence. According to this framework, if the higher-level model shows properties that the lower-level model fails to show, then this case implies emergence. In the case of critical phenomena, the RG framework maps the lower-level model, which fails to show the critical phenomena, onto a higher-level model, which provides explanation of the phenomena. Therefore, this is a case of emergence. In contrast, Saatsi and Reutliger (2018), for instance, point out that the RG framework does not immediately imply anti-reductionism. Certainly, the RG transformation does not completely ignore the details and a link between models is required in De Haro's framework of emergence. This talk focuses on the relationship between models regarding phase transitions. Our aim is to clarify what kind of links or transformations between models imply emergence, comparing the case of critical phenomena with superconductivity.

16h30-17h45 – **Andreas Hüttemann** (University of Cologne) Phase Transitions and the Causal Exclusion Argument

In the talk the example of reductive explanations of phase transitions will be used to discuss causal exclusion and to illustrate the feasibility of non-reductive physicalism.

8h45-9h30 – **Johannes Martens** (CNRS, Sorbonne Université) Darwinian Indivisibility, Egalitarian Transitions and the 3-layered Model

I shall discuss an important contrast between two (broad) construals of the notion of an evolution transition in individuality (ETI), itself rooted in a more fundamental opposition between two conceptions of a Darwinian individual.

As is well known, an ETI is usually represented as a process during which most of the selective forces happen to be "transferred" from the lower to the higher level, so that, at the end, the bulk of the adaptations end up being concentrated at the level of the collectives, and the entities at the lower level turn out to be largely "de-Darwinized" (Michod 1999; Godfrey-Smith 2009, 2013; Clarke 2016). On this account, an ETI is thus equivalent (at least at a first approximation) to the emergence of a distinctive population of "Darwinian indivisible units"—that is, a population of Darwinian individuals that are no longer "made of" (actualized) Darwinian individuals.

So far, this theoretical definition—together with the notion of "Darwinian indivisibility"—has often been employed (more or less explicitly) as a general heuristic to think about the nature and variety of ETIs. But the very idea of a "Darwinian indivisible unit" (originated in Godfrey-Smith's 2013 seminal paper) is also quite equivocal; for two different "measures" can actually account for the presence of an "indivisible core" at the collective level. The first, as I will show, emerges from a rather classical trend in the unit-of-selection debates (Williams 1966; Okasha 2006; Sober and Wilson 2011), and stipulates—very roughly—that a genuine Darwinian indivisible unit should be the ultimate beneficiary of the adaptations that it possesses—with the crucial requirement that $rb > 0$ (Birch 2018), and granted a rough synonymy between the notion of a "beneficiary" and the Lewontinian definition of a "unit of selection". (Here, the key assumption is that a Lewontinian unit of selection/adaptation only exists at a level N whenever there are indirect benefits at the level $N - 1$). The second measure derives, by contrast, from the assimilation of the class of Darwinian individuals to a particular subclass of reproducers, and emphasizes the transfer of the capacity of reproductive autonomy from the lower level to the organismal level (Griesemer 2000; Godfrey-Smith 2009, 2013, 2015).

Prima facie, these two measures stand out as legitimate (and desirable) criteria that any Darwinian indivisible unit should satisfy. But both, in practice, ultimately disagree upon the things which fall upon the extension of the "ETI" concept, leading to an apparent inconsistency in the very characterization of its domain. Thus, the "beneficiary requirement"—properly understood—doesn't allow for the recognition of any symbiotic (i.e. "egalitarian") instances of this concept (since $r = 0$ in those cases), whereas the “reproductive autonomy requirement”, in contrast, admits of a non-empty set of egalitarian transitions, such as the “classic” mitochondria/eukaryotic cells association—though at a parsimony cost (the parsimony cost is a consequence of the fact that, in the case of egalitarian associations, we do not need to posit the whole association as a “beneficiary” to account for the dynamics of its evolution).

In this presentation, my primary goal will be to sketch out a general solution to this puzzle (parsimony vs. generality) by proposing a theoretical model which not only accommodates the two abovementioned measures of Darwinian indivisibility, but also reconciliates the need to include some (uncontroversial) egalitarian transitions with the kind of parsimony considerations relative to the beneficiary requirement. To this end, I argue that, contra appearances, these two “measures” do not embody mutually exclusive interpretations of the concept of a Darwinian indivisible unit, but represent rather different “kinds” of such units, which both need to be integrated in a specific sort of 3-layered compositional structure (the units of the first kind being the proper parts of the units of the second kind) to fully account for the case of egalitarian ETIs.

9h30-10h45 – **Samir Okasha** (University of Bristol) Reductionism and Evolutionary Transitions

Evolutionary transitions in individuality have occurred repeatedly in the history of life on earth. They occur when formerly free-living entities coalesce into a larger unit, which then becomes a new higher-level individual. Much work in evolutionary biology has been done on such transitions over the last 25 years. A distinction has been drawn between "genic" and "hierarchical" approaches to explaining evolutionary transitions. The former is reductionistic, the latter "holistic". However, despite much discussion, it remains unclear whether this distinction is one of perspective or objective fact. I argue that the unclarity can be resolved by drawing on the theory of causal graphs, and by seeking explicit criteria for when two evolutionary explanations should be judged equivalent.

11h15-12h30 – **Fridolin Gross** (University of Bordeaux) Three Regimes of Biological Complexity

I present my conceptual analysis of biological complexity as a property that depends on both the relevant causal structure and the behavior of interest of a system. Making this dual dependence explicit allows me to distinguish between three different regimes of complexity, which I call "emergent complexity", "mechanical complexity" and "unnecessary complexity", respectively. Building on this analysis, my talk will focus on two further topics: first, the relationship between complexity and explanatory reductionism, and second, the evolutionary transitions through which the different types of complexity can arise.

14h00-15h15 – **Tarja Knuuttila** (University of Vienna) Mechanistic Reduction, Abstraction, and Unification: Uri Alon's Network Motifs

Mechanistic explanations are due to a particular kind of reduction: explanations appeal to localized and isolated mechanisms consisting of component parts and their operations, and organization arising from those operations. Moreover, it is possible to further decompose those parts into lower level mechanisms. However, the mechanistic approach has some problems in accommodating abstract mathematical modeling. Are abstract models only schematic how-possibly explanations, as Craver (2006) has suggested, or is something else at stake? One answer is to invoke mechanistic abstraction as that of ascending upper levels in the mechanistic explanations. Boone and Piccinini (2016) claim that each higher level abstracts away some of the details of lower-level mechanisms. They refer to Levy and Bechtel's work on Uri Alon's network motifs as an example of such mechanistic abstraction. Levy and Bechtel (2013) argue that network motifs study the temporal organization in biological systems by omitting information about specific parts and interrelations and concentrating on causal connectivity. I aim to show that the construction process of network motifs does not support the idea of abstraction as omission of mechanistic details. Instead of such interpretation, network motifs should be given a modal reading that emphasizes their template-like unifying character.

15h15-16h00 – **Alexandre Guay** (University of Louvain) – Topological Transitions in Quantum Fluids

The Landau-Ginzburg theory has been immensely successful to model different states of matter. In this theory, order is associated with spontaneous symmetry breaking described using group theory. For many decades now, new states of matter have been experimentally produced (e.g. Hall fluids). In these liquids, matter is strongly correlated and has an internal structures, like in a solid, however the implied order cannot be characterized by symmetry breaking of local order parameters. In other words, to understand these states of matter, we have to go beyond the Landau-Ginzburg approach and, as sustain by Xiao-Gang Wen (2004), develop a new classification of orders, especially what he called topological orders. Moreover this notion of order should be introduced via quantities that can be measured. This talk sets out to achieve three primary objectives:

1. Evaluate Different Notions of Order: This involves a critical examination of various proposed notions of order to discern whether they represent an evolution or a transformation from the concept as envisaged in the Landau-Ginzburg theory. The development of topological order, particularly noted for its adherence to measurable quantities, provides an intriguing backdrop for this analysis. The theories of Nussinov and Ortiz (2009a, 2009b), which continue to honor symmetry principles, will be scrutinized in detail to facilitate this comparison.

2. Explore the Concept of Topological Transition: Inspired by Continentino (2017), this section will delve into the implications of topological order on our understanding of phase transitions. The inquiry will center on whether topological transitions introduce an entirely new paradigm or if they are fundamentally analogous to traditional notions of phase transition.

3. Investigate the Notion of Transition as Ontological Emergence: The final aim is to discuss how this novel perspective on transitions might exemplify a case of diachronic ontological emergence, as suggested by Humphreys (2016) and Guay and Sartenaer (2016). The hypothesis posits that quantum fluid transitions offer the most compelling evidence yet of such emergence.

16h30-17h45 – **Margarida Hermida** (King's College London) Biophysical Constraints and Major Evolutionary Transitions

Natural selection displays no inherent tendency for increasing complexity. Life on Earth originated very quickly, but took a long time to become complex. An important reason for this is that cells face biophysical constraints on their size and complexity that can only be overcome through increases in hierarchical complexity, i.e. through the emergence of organisms composed of other organisms. Although multi-level selection and conflict mediation played important roles in these transitions, biophysical factors are essential for understanding how life can become complex. Prokaryotic cells face strict biophysical constraints on size due to physical laws of diffusion and energy requirements. As they obtain energy through chemiosmosis across the cell membrane, they must retain a high surface-to-volume ratio, which limits their size. In the transition to the eukaryotic cell, the acquisition of endosymbionts that became the mitochondria decoupled respiration from the cell membrane, allowing eukaryotic cells to overcome the strict surface-to-volume constraints facing bacteria. The bioenergetic advantages of endosymbiosis resulted in a vast surplus of energy available for biosynthesis that permitted the evolution of much larger genomes, opening the door to the evolution of structural and morphological complexity (Lane & Martin 2010). Similarly, biophysical constraints involving mechanical properties of cells preclude single-celled organisms from achieving very large sizes, which again can only be overcome through the evolution of multicellularity. Since life anywhere in the universe will inevitably face the same biophysical constraints, we should expect alien life to either be bacteria-like, or else to have undergone evolutionary transitions very similar to those of Earth life.

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