Physics at the Interface

Connecting the Philosophy of the Physical, Life and Social Sciences

7-8 September, Birley Room, Hatfield College,
Durham University

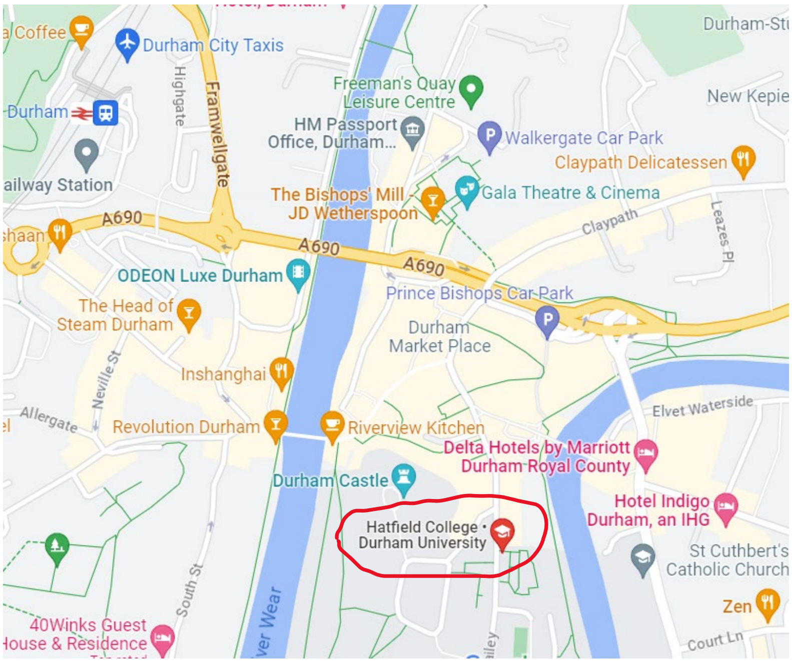
The 21st century has seen the flourishing of interdisciplinary fields at the interface of physics and other disciplines, such as biophysics, econophysics and social physics. The gap between physics and chemistry has also become increasingly blurred. The transfer of concepts, models and methods from physics to other domains raises a host of pressing questions. How does the interpretation, justification and explanatory status of physics approaches change when they are applied to biological and social systems? Do methodological conflicts arise at the physics interface, and if so how might historians and philosophers of science address them? There are also questions about the relationship between work in the philosophy of physics and other sciences. Can ideas from the philosophy of physics shed light on problems in the philosophy of biology, chemistry and the social sciences, and vice versa?

This workshop will be amongst the first to bring together researchers interested in philosophical issues that arise at the physics interface.

Venue

We will meet in the Birley Room, Hatfield College at 12:30 7 September for lunch.

To get to Hatfield College, follow Saddler Street from Market Square uphill toward the Cathedral. Hatfield will be on your left, after the History Department (which is 43 North Bailey). Enter the college through the main gates, take a rightafter the tennis court and follow signs to the Birley Room. The college porters can guide you if you have any trouble.



Schedule

7 September

12:30-13:30 Lunch + Welcome

13:30-14:20 Margarida Hermida “Physical Explanation and the Autonomy of Biology”

14:20-15:10 Simon Peres “Crafting and Experimenting: Materials at the Interface of Physics and Anthropology”

15:10-15:30 Coffee Break

15:30-16:20 Vanessa Seifert “The Many Laws of the Periodic Table” (online)

16:20-17:10 Robin Hendry “How (Some) Disciplines Emerge”

19:00 Dinner

8 September

10:20-11:10 Callum Duguid “Metalaws in Biology”

11:10-12:00 Uzma Malik “Stretching - from Physics to Biology”

12:00-13:30 Lunch

13:30-14:20 Jennifer Juhn “Analogies in Econophysics (and Beyond)”

14:20-15:10 Ufuk Tasdan “Econophysics in Finance: Modelling and Performativity”

15:10-15:30 Break

15:30-16:20 Alexey Burluka “Turbulence Theory Formalism for Quantifying Distribution of Societal Contentment”

16:20-17:10 Alexander Franklin “Social Construction, Physical Construction, and Emergence”

Abstracts

Alexey Burluka
Turbulence theory formalism for quantifying distribution of societal contentment

Standard questionnaire-based approaches in sociology for quantifying life satisfaction have not as yet produced a method capable of quantitative predictions of societal contentment distribution; it is obvious that such method has to take into account effects of economics as well as subjective individual perceptions. Such method is established here using a mathematical formalism successfully used in description of turbulent reactive flows but completely alien to social sciences. A continuous bounded variable is introduced to characterise contentment, or satisfaction with life, of an individual and an equation governing its temporal evolution is postulated from analysis of several factors likely to affect the contentment. These factors range from fleeting feelings to overall state of economy, they are formalised through an estimation of their characteristic times, with combined action of short-time scale factors taken as a random "jumps". As contentment is strongly affected by the material well-being, a similar evolution equation is formulated for wealth of an individual. Parameters in that wealth equation are fitted to provide an approximation to the UK/OECD values averaged over the last 40 years. From the two equations for the evolution of individual contentment and wealth a balance equation for joint probability density function (pdf) of contentment and wealth in a society is obtained following methods well established in turbulence theory; in particular, effects of marriage which is essentially a pairwise interaction of individuals, are described as an integral "mixing" term similar to what used in turbulent combustion theory. As an illustration of this model capabilities, effects of the wealth tax rate over a long period of time are simulated for a society with an initially low variation of wealth and contentment: the model predicts that a higher taxation in the longer run may lead to a wealthier and more content society. It is also shown that lower rates of the wealth tax lead to pronounced stratification of the society in terms of both wealth and contentment and that there is no direct relationship between the average values of the latter two variables thus providing an explanation to the Easterlin paradox.

Callum Duguid
Meta Laws in Biology

Symmetries play a central role in contemporary physics. It follows from Noether's (first) theorem that the well-known conservation laws are tied to principles of symmetry, in the sense that they are interderivable. Many authors have connected physical symmetries to explanation, claiming, for instance, that Permutation Invariance explains the nature of quantum statistics. That the physical laws abide by symmetry principles is seen today as no mere accident: the latter are treated as guiding principles which we expect future laws to accord with.

A prominent advocate for philosophical consideration of symmetries is Marc Lange who treats them as 'metalaws' (that is, second-order laws). The purpose of this paper is to suggest that we can utilise this conception to make sense of the connection between certain kinds of biological principle and the associated patterns in the biological phenomena. Put simply, I argue that we should make room for metalaws within the philosophy of biology.

One example of a biological candidate for lawhood is Kleiber's 'law', which relates an organism's metabolic rate to its mass. It is a remarkably stable generalisation which holds over both single-celled bacteria and blue whales. The relevant equation contains an exponent term close to 3/4. One explanation for why the term takes this value has been offered by West, Brown and Enquist (WBE). The WBE model treats organisms as having a transportation problem to solve: what is the best system for transporting materials to the cells that require them? For reasons concerning energy efficiency, they argue that organisms will possess a fractal branching transportation system. This then allows them to mathematically derive the quarter-power law. The same considerations are then appealed to in order to explain a broad swathe of similar allometric power laws.

Treating the WBE model as capturing a metalaw concerning allometric power laws provides a place for it within an established theoretical framework. WBE's reasoning shows both the explanatory and predictive features that metalaws possess: they take themselves to have demonstrated why Kleiber's law contains a 3/4 term and they use their reasoning to predict the values of exponents in other equations. Such predictions demonstrate the intended counterfactual robustness of WBE's reasoning: they take the principles embedded in their model to remain constant over a broad range of different circumstances. These usages are justified if we are dealing with a second-order law concerned with first-order biological regularities.

Both Kleiber's law and the WBE model have been subject to a variety of criticisms. However, there is still something of philosophical value to be extracted from this example. As the literature on the WBE model attests, it has been taken seriously by working biologists. Our philosophy of biology should be capable of accommodating this without pre-judging its success from the armchair. Whether there are in fact any metalaws in biology should be determined by the relevant science; the role of philosophers here is to build an account where the goals of WBE's project make sense. Allowing for biological metalaws and treating the WBE model as aiming at capturing one does exactly that.

Alexander Franklin
Social Construction, Physical Construction, and Emergence

Can the nature of inter-level relations in physics give us insights into such relations within social reality? Is there anything in common between the way that viscosity emerges from the more fundamental structure of fluids and race's relation to the structure of society? Or is the common appeal to 'structure' mere polysemy? In this talk I'll explore various responses to these questions and defend the claim that identity-based bridge laws are inadequate to real case studies both in the physical and social sciences. I'll then discuss alternative models for inter-level relations inspired by physics examples and suggest that this may solve a central problem faced by accounts of the social construction of human kinds. I'll conclude by considering what morals we should draw from the fruitfulness of such interdisciplinarity.

How (Some) Disciplines Emerge
Robin Findlay Hendry

Emergence provides one kind of explanation for why there can be autonomous special sciences. In this paper I examine some well-known proposals for how this might work, appealing to independent organising principles and novel entities. I also examine some key examples from chemistry and condensed matter physics. Examples of intertheoretic explanation in these disciplines are importantly different from others in the philosophical literature, because they have been (or have always been) commensurate with fundamental physics. There seems to be no difficulty in connecting the different theoretical vocabularies or concepts. Reductionist philosophers of mind tend to dismiss the non-derivability of emergent phenomena as an adequate criterion for emergence, but I will argue that it remains key to judging the significance of emergence in these kinds of cases.

Margarida Hermida and James Ladyman
Physical Explanation and the Autonomy of Biology

Following the demise of vitalism, some philosophers considered biology to be a temporary science that would ultimately be reduced to physics. In opposition to these views, Mayr and others presented several arguments for the autonomy of biology. These moderate autonomy theses include the claims that biology is a genuine science, with its own concepts, methods, problems, and theoretical approaches, which distinguish it from other sciences (Aut-m), and the thesis that biology cannot be explanatorily reduced to physics (Aut-irr). There are good reasons to affirm these claims.

However, stronger autonomy theses are often hinted at in the literature, although seldom explicitly stated. These include the thesis that physical laws are irrelevant for biological explanations (Aut-irrel); that biological phenomena cannot have physical explanations (Aut-ex); and that biology is no less fundamental than physics (Aut-fund). Here we are concerned with Aut-ex.

If Aut-ex is understood as the claim that biological phenomena must be explained *only* in terms of biological terms and principles, then it is false, because physical explanations also play a role in explaining biological phenomena. For example, although the behaviour of a predator is better understood in terms of its biology and ecology, facts about metabolism and the physical mechanism of ATP production are not irrelevant for the explanation of why it needs to eat, why it has certain evolved traits that allow it to feed on other organisms from which it obtains organic compounds for oxidation, etc. Another interpretation of Aut-ex is that there cannot be physical explanations of biological phenomena. On this view, physical explanations are, at best, complementary to biological explanations. Here we dispute this claim on the basis of two case studies.

The first is the case of cataracts in children, caused by mutation in the human γ-D crystalline protein. A biophysical study of this protein discovered that although certain point mutations do not change protein structure significantly, they dramatically alter its solubility profile, reversing the relationship between solubility and temperature, due to anisotropic interprotein interactions. This results in a phase transition at physiological temperatures that causes lens opacity. This is a good example of a biological phenomenon that has a physical explanation, and the fact that interactions between proteins are an important component of the explanation illustrates how reductive explanations rely on interactions between parts.

The second case study is the cohesion-tension theory of water transport in trees. The main driving force for water transport in trees is transpiration in leaves. Water is transported from the roots up to the leaves through the xylem, which consists of long thin capillary vessels, filled with a continuous water column. Transpiration in leaves produces a negative pressure gradient that pulls the water upwards against gravity. The continuous water column maintains its stability due to cohesion between water molecules and adhesion to the inner surface of the vessels, both of which result from physical properties of the water molecule, especially its polarity. This example shows that physical laws enable and constrain the functioning of biological systems, and they are often at the heart of both the problems and solutions encountered by evolving biological systems.

The case studies demonstrate that some biological explanations are physical explanations, and also that which scales and laws are explanatorily relevant for a particular phenomenon must be decided by scientific discovery, not a priori.

Jennifer Jhun
Analogies in Econophysics (and Beyond)
Based on joint work with Patricia Palacios

Econophysics is sometimes criticized for failing to satisfactorily establish analogies to their physical counterparts. We diagnose more precisely why it is that econophysics models seem unsatisfactory and suggest one way of reconceptualizing the problem, as well as possible solutions. This exercise also suggests some cautionary lessons to those who aspire to undertake similar projects connecting economics with other sciences, especially biology.

Uzma Malik
Stretching - from physics to biology

This paper will show one way that lessons learnt from physics can apply to biology and even the social sciences. I will start with Robert Batterman's 2009 paper where he discusses the treatment of breaking water drops taken from physics as an example of minimal model explanation. Usual accounts of scientific explanation suppose that models explain by representing common features the model has with real world systems. Minimal models are explanatory in virtue of an alternative connection.

I will reconstruct both Batterman's physics breaking drops model and an analogous example from biology in a way that makes clear they have similar explanatory structure. The biology example is RA Fisher's one-to-one sex ratio as a minimal model which Batterman and Rice suggest can be recast as a minimal model explanation but do not themselves properly carry off (Batterman and Rice 2014). I will then take from this shared structure what I need to construct my own theory of scientific understanding: local unification which can be applied successfully to biology and the social sciences. My theory solves the problem that Batterman and Rice have been trying to solve by applying physical concepts in a biological context. These physical concepts include the renormalisation group method and its analogues and university classes. These concepts are vital physical concepts that play a key role in minimal model explanations. Indeed, the whole point of minimal model explanations is to put systems into a relevant universality class via the renormalisation group methods or its analogue.

For instance, consider this very important step that Batterman and Rice 2014 take in discussing the merits of minimal model explanations in a biological context say:

> *Suppose we could delimit the class of systems exhibiting a one-to-one sex ratio from other systems that fail to display this macro behaviour. This would be to delimit the universality class that can account for the safety of using minimal models*

Here Batterman and Rice write as though they suppose that if we could demonstrate that the minimal model can be put into a relevant universality class, we can have an answer to the question why Fisher's minimal model can be used to explain the behaviour of biological populations.

a. biological populations can be shown to be part of the relevant universality class by demonstration with the help of a minimal models.

b. This minimal model is also demonstrated to be in the same class.

The main point I wish to make in this paper is that simply stating the procedure (as above) is not enough for understanding Fisher's sex ratio model as a minimal model. It is not enough that it is not shown or demonstrated how Batterman and Rice's minimal model of Fisher's one-to-one sex ratio gets put into its universality class. For the breaking drops example there is an analogue of the renormalisation group method for putting systems into that particular universality class or not, but this is missing from the case in biology. My theory of LU does this by abstracting or to a more general level that loses the physical language of universality classes etc so it can stretch from cases in physics to biology and the social sciences.

Simon Peres
Crafting and Experimenting: Materials at the Interface of Physics and Anthropology

Much of the recent philosophy of the physical sciences has been concerning itself with the epistemology of intervention, especially as it relates to modelling: how can we know physical reality by manipulating it into new forms? How can models guide interventions, and can some operational or interventional practices constitute models per se? In tackling these questions, much of this literature aims to locate science's capacity to reach reality not in its body of theory, but in its coherent practice. In parallel, some strands of social anthropology have been approaching craft not simply as a manifestation of abstract social structures, but as an epistemically valuable activity in itself. To make things is to enter a process of responsive attunement to one's environment which, as Tim Ingold would put it, enables one to know it from the inside. What these two programmes share is a clear, yet under-theorised interest in materials, both as a (hitherto neglected) branch of science and as a type of entity. I will show that this is not a coincidence. Materials form a privileged interface between physics and craft in two distinct, yet interlinked ways. Firstly, they irreducibly sit between the scientific and the manifest images of the world, their individuation for scientific study never entirely separated from potential instrumental prospects. This calls for a reunited account of intervention and manipulation, in which the experiments of materials science and the creations of craft are understood as engaged in a common task, that of identifying and exploiting material spaces of possibility. Secondly and consequently, they incite us to resituate the philosophy of physics within a general anthropological framework. Physics is one of the ways humans inhabit their environment, and it is within this context that its practices of modelling and intervening should be understood.

Vanessa Seifert
The Many Laws of the Periodic Table

Reference to a 'periodic law' commenced from the very first classifications proposed for chemical elements. From Newland's and Meyer's classifications to Mendeleev's periodic table, talk of a 'periodic law' was commonplace and persists to this day. Yet, despite the significance that laws of nature have had in philosophical discourse, philosophers have either not picked up on or have undermined the periodic table's relevance to the discussion of lawhood. In light of this, I examine whether and in what way the periodic table can be regarded a representation of a law of nature. I claim that the table represents multiple law-like regularities about (different sets of) chemical elements. These statements include for example that 'Halogens undergo redox reactions with metal halides in solution'; 'Tantalum is chemically inert, with very high melting point'; 'Actinium reacts rapidly with oxygen'; and 'Lanthanum reacts with the halogens at room temperature'. That is, the periodic table is a (visual) depiction of regularities between individual elements, between sets of elements, and between elements and sets of elements. Therefore, I argue that if the periodic table represents a law of nature, it represents many laws of nature. This shouldn't come as a surprise; the table identifies 118 elements, 18 groups and 7 periods, positing various regularity relations between them about- among other things- their chemical reactivity, their (non)metallic character, their electron affinity and ionisation energy. To support this claim, I present key features typically assigned to laws and show how they apply to the regularity relations expressed in the periodic table. These features include the role of laws in inductive inferences and counterfactual reasoning; their predictive power; their ability to unify the behaviour of prima facie disparate things in the world; as well as their ability to systematise empirical facts. I show that these features are satisfied by the lawful regularities represented in the table. I then consider two challenges to the claim that the periodic table represents laws of nature. First, it is argued that the table does not have genuine predictive power, thus undermining a standard feature of laws. Secondly, it is argued that the periodic table is explanatorily redundant because quantum mechanics explains the relevant phenomena. I argue that both challenges can be overcome thus reinforcing the claim that these lawful regularities correspond to laws of nature. In conclusion, whether the periodic table represents laws of nature is far from uncontroversial. Nevertheless, it is a novel issue in metaphysics that can inform our understanding of laws and offer a renewed appreciation of the periodic table's significance to science.

Ufuk Tasdan

Econophysics in Finance: Modelling and Performativity

Econophysics, a developing discipline combining principles from economics and physics, has garnered considerable interest in recent times due to its innovative methodology in modelling intricate economic systems. However, there is still insufficient clarification regarding the ontological nature of these models when viewed from the perspective of applying econophysics, as the concept of performativity is rarely addressed. Our objective in this study is to examine the significance of performativity within the field of econophysics in finance, as viewed by a practitioner—so called ”quants”. Do these models solely serve as phenomenological representations without incorporating any underlying theoretical mechanisms, or do they possess explanatory capabilities1? In essence, the question arises whether it is advisable to adopt an anti-realist stance in econophysics, wherein the underlying mechanisms of markets are either non-existent or unknowable, and econophysics is solely concerned with blind data-driven modelling. Alternatively, even if markets adhere to the random nature as defended by Malkiel (1999, 2003, 1996), can we gain insights into its inherent characteristics by predicting volatility? A potential solution to address this issue involves conducting a performance comparison between econophysics funds and other funds. Nevertheless, there are no trading firms exclusively employing econophysics. Furthermore, within the field of econophysics, researchers also utilize econometrics' methods. For instance, Bunde et al. (2002) states that "[i]n most cases, there are no material differences in the empirical results reported by researchers from economics and finance-aficionados from physics." (p. 404). Moreover, due to privacy policies implemented by companies, it is challenging to find papers from quantitative researchers/traders that present specific strategies with successful forward testing. Derman (2016) in his book—called My Life as a Quant: Reflections on Physics and Finance—says "We were forbidden from publishing it because it was proprietary; yet often, no one inside the company had any real use for it." (p. 101). This phenomenon can be attributed to the concept of performativity, wherein the disclosure of any publicly available trade signal opportunity leads to its subsequent disappearance. Within the academic literature, the predominant focus revolves around specific econophysical models and their compatibility with particular data points, ultimately determining their effectiveness in generating profitable outcomes during backtesting. Nevertheless, the process of backtesting does not provide assurance for forward testing and therefore cannot be considered a reliable indicator of a model's actual success. Considering the close relationship between econophysics and econometrics, along with the limitation of not having access to the internal reports of companies to evaluate the success of econophysics, and considering the influence of performativity, how can we determine the effectiveness of the models in explaining phenomena? In this work, our aim is to discuss the modelling of finance by econophysics through the lens of quants in the industry.

List of Speakers

Alexey Burluka (Northumbria University)

Callum Duguid (University of Leeds)

Alexander Franklin (Kings College London)

Robin Findlay Hendry (Durham University)

Margarida Hermida (University of Bristol)

Jennifer Jhun (Duke University)

Uzma Malik (Durham University)

Simon Peres (University of Aberdeen)

Vanessa Seifert (University of Athens)

Ufuk Tasdan (University of Bristol)