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Markus Gabriel *Editors*

Top-Down Causation and Emergence

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Introduction

In Honour of George Francis Rayner Ellis

George Ellis is universally recognised as one of the leading cosmologists of our time. A gifted applied mathematician and theoretical physicist, he is a world-renowned expert on the theory of relativity, space-time, complexity, and causality. In addition, however, his rare depth of insight combined with an uncanny knack for grasping the deep systematic import of any given scientific issue also makes him what can only be described as a true philosopher of nature, however much that term might have fallen out of fashion. Throughout his career, he has been an embodiment of the scientific ideal, cherished as a model teacher by his students and held in the highest esteem by his colleagues. For many of us philosophers, at least, it is difficult to appreciate the sheer range and complexity of George's numerous contributions, let alone to grasp the significance of his work across such a variety of scientific fields. To be sure, we members of the scientific laity are likely to know his classic collaboration with Stephen Hawking on space-time, *The Large Scale Structure of Space-Time* (1973). Likewise, he is widely known for having co-authored standard works on relativistic cosmology, including *Relativistic Cosmology* (2012) with Roy Maartens and Malcom MacCallum, as well as for the famous *Dynamical Systems in Cosmology* (1997), co-edited with John Wainwright. Yet these three books represent only the tip of the iceberg: George is responsible for a series of highly influential monographs, collections and journal articles spanning the fields of general relativity, relativistic cosmology, cosmological models, and complex systems, which together make up an overall contribution that has proved to be as groundbreaking as it is vast.

To assess the whole body of George's work in a brief introduction would therefore be a hopeless endeavour. Yet, even if we limit ourselves to the field of philosophy, George has been responsible for significant innovations in a number of different subdisciplines. For well over two decades, his interests in causation, emergence and cosmology have taken a distinctly philosophical turn, and he has published what are perhaps the most influential pieces on top-down causation in recent scholarship, successfully bridging philosophy, physics, the life sciences and

mathematics in a way that few—if any—can hope to emulate. The remarkable theory of the causal structure of the universe, complexity and emergence, that he put forward in his much-discussed *How Can Physics Underlie the Mind? Top-Down Causation in the Human Context* (2016) together with numerous highly regarded articles, has sparked widespread academic discussion. In addition, his keen interest in ethics, moral philosophy and theology has been equally productive, resulting in the publication of a volume of collected papers, numerous articles, book chapters and monographs including, among others, the highly regarded *On the Moral Nature of the Universe: Cosmology, Theology, and Ethics* (1996), co-authored with Nancey Murphy.

All these achievements contribute to his status as one of the most outstanding scientists and scholars of recent decades. They are the fruits of a highly impressive career of which we can here mention only a few of the key landmarks: Following his graduation with distinction in physics at the University of Cape Town in 1960, he went on to study at St. John's College, Cambridge, where he was awarded a PhD in Applied Mathematics and Theoretical Physics in 1964. His first academic positions were at the University of Texas, Austin, and the University of Cambridge, where he became a lecturer in the Department of Applied Mathematics and Theoretical Physics in 1970. In the following years, he was a visiting professor at the University of Chicago's Fermi Institute, the University of Hamburg and the University of Boston, before his appointment as Professor for Applied Mathematics at his alma mater in Cape Town in 1974, a chair he occupied until 2004, when he became Emeritus Professor and Honorary Research Associate at the very same department. Since taking up his position in Cape Town, he has been invited as a distinguished visiting professor at a number of illustrious institutions: the University of Alberta at Edmonton, the University of Texas at Austin, Specola Vaticana at Castel Gandolfo, Queen Mary College at the University of London, the University of Oxford, the University of Cambridge and, as a frequent visitor, the Max Planck Institute for Astrophysics in Munich. From 1988 to 1993 he was Professore Ordinario of Cosmic Physics at the International School for Advanced Studies in Trieste, and in 1988 he also became GC MacVittie Visiting Professor of Astronomy at Queen Mary and Westfield College of the University of London, a position he holds to this day.

In light of his manifold scientific achievements, contributions to philosophy and theology, and social and political engagement, he has been the recipient of multiple honours. To name but a few: since 1983, he has been a Fellow of the Royal Society of South Africa, of which he was also President between 1992 and 1996; he was appointed a Fellow of the Royal Society in 2007; and naturally, he has been decorated with the highest possible recognition of the National Research Foundation of South Africa. For his contributions to furthering the dialogue between science and religion, he was awarded the Templeton Prize in 2004. Beyond the scholarly sphere, he was recognised with the Order of the Star of South Africa in 1999 for his history of vocal opposition of Apartheid. In addition, he was President of the International Society for General Relativity and Gravitation as well as of the International Society for Science and Religion. As a founding and council member of the Academy of Science of South Africa and a Fellow of the Third World Academy of Science, he

has served the academic communities in South Africa and the Global South. He holds honorary doctorates at seven different universities spanning three continents: Africa, North America and Europe.

As we have known him for only a few years, we can only bestow George with a much more modest honour: for his 80th birthday, we would like to offer him the small, belated gift that is this collection. Of his many accomplishments, it was his theory of top-down causation and emergence which first led our paths to cross. This part of George's work, which is truly interdisciplinary in the best sense of the term, forms the focal point of the following contributions. The many colleagues who have participated in the creation of this volume have conceived their respective contributions as expressions of their respect and admiration for George's industry, intellectual example and human kindness.

This Festschrift assembles a diverse and distinguished group of collaborators. The transdisciplinary diversity it represents is only fitting for a collection compiled in honour of George, and the volume is intended to reflect both the scope of his own scientific and philosophical interests and his talent for perceiving unlikely yet consequential connections between different topics and fields. Furthermore, many of the essays that follow are parts of ongoing discussions: many of the contributing authors were able to discuss the questions raised in the volume with George himself at a conference held at Bonn in the summer of 2018 on his theory of top-down causation and emergence. In the following section, we outline the structure of this anthology and offer a preview of each of the contributions. This also affords us an opportunity to briefly introduce the reader to the debate on top-down causation and emergence, with a particular focus on George's own outstanding contributions to the field.

The Contributions to This Festschrift

Applications of George Ellis's Theory of Causation, the first of five parts of this anthology, contains three chapters. Each of these focuses on a different aspect of the grand theory of complexity, causality and the structure of nature proposed by George Ellis. Of the many recent theories of the causal structure of the universe, whether proposed by scientists or philosophers, only a small handful are truly applicable to all areas of nature and within all scientific disciplines that are in the business of making causal claims. And even fewer theories have the additional advantage of shedding philosophical and scientific light on the emergence of genuine complexity and thus of counting as contributions to the study of complex systems. In this respect, Ellis's theory seems to represent a genuine rarity, and the task of applying it to a range of different test cases—from philosophy through to the social and natural sciences—promises to be especially fruitful.

The first chapter, by **George F. R. Ellis** and **Markus Gabriel**, entitled *Physical, Logical, and Mental Top-Down Effects*, is a multidisciplinary essay exploring the architecture and applicability of the theory of top-down causation in three different

contexts. The first is the physical universe: here, Ellis and Gabriel assess how top-down effects are possible in the case of physics, with reference to the fact that the physical universe is not closed at the lower levels. They argue for the importance of contextual effects, which include examples from both biology and neuroscience. In a second step, citing a number of examples from such different fields as logic, mathematics and the social sphere, they argue that abstract objects have causal effects on material-energetic systems. They conclude that only a theory of top-down causation is able to account for the role played by abstract objects in knowledge acquisition, which in turn has the consequence that strict reductionism about abstract objects undermines the possibility of knowledge. In a concluding section, Ellis and Gabriel tackle the problem of mental causation by sketching a model for mind–body interaction that arises from both Ellis’s theory of causation and complexity and Gabriel’s neo-existentialism in the philosophy of mind. This lead chapter thus takes up various threads in the work of both authors; it attempts to provide a suitable philosophical language and framework for certain well-established components of Ellis’s theory while also expanding it into new subject domains.

The second chapter, by **Sara Green** and **Robert W. Batterman**, *Making Sense of Top-Down Causation: Universality and Functional Equivalence in Physics and Biology*, investigates a key aspect of Ellis’s theory: the relationship between the notion of top-down causation and functional equivalence classes. The latter is the conceptual tool that allows Ellis to explain how a specific higher-level behaviour can be multiply realised by different lower-level systems or states. By highlighting what Green and Batterman call *causal slack between levels*, they explain the apparent independence of higher-level phenomena from lower-level conditions. Through exploring cases from physics and biology, Green and Batterman argue for an extension of Ellis’s account of mechanical top-down causation and top-down causation by information control which involves causal slack. The authors argue that this modification to the theory of mechanical top-down causation has the additional merit that it presents an even greater challenge to reductionism.

The third chapter, by **Otávio Bueno**, is entitled *Mathematics and Measurement: Causation and the Mind*. It tackles the question of what causal roles mathematical structures could play in causal processes and the linked question of how to construe measurements in light of Ellis’s theory. Bueno argues that while mathematical structures might be important for causal processes it is not clear that they need to be causally efficacious, as Ellis suggests. Guided by an empiricist understanding of scientific theorising, the first part of Bueno’s article aims to support the idea that while mathematical structures are causally inactive in virtue to their abstractness, they play a role in causal processes via their interpretation and use as representations by agents. The second topic of the paper, how measurement should be understood in light of Ellis’s theory, is connected to this insight: According to Bueno, agents play the same causally active role in a measurement process, making it an example of top-down causation.

The second part of our collection, **The View from Physics**, explores Ellis’s theory from the perspective of different subdisciplines of physics. It contains two quite distinct contributions:

The fourth chapter, by **Barbara Drossel**, is entitled *Strong Emergence in Condensed Matter Physics*. It investigates whether a micro-physicalist reductionism, which argues for causal closure and determination in a bottom-up fashion, or a theory of top-down causation, is best suited to explain the effects and laws central to condensed matter physics. Drossel argues for the conclusion that Ellis's theory is superior from this perspective. She begins by giving a series of examples of condensed matter systems that show emergent phenomena. After drawing a distinction between weak and strong emergence, she investigates texts by three Nobel laureates in condensed matter theory and demonstrates how condensed matter research is conducted in practice, supplemented by insights from her field of expertise, statistical physics. Based on this analysis, she presents a list of reasons for accepting strong emergence in physics and discusses certain widespread objections to the view.

The fifth chapter, by **Thomas Luu** and **Ulf-G. Meißner**, takes a completely different route: in *On the Topic of Emergence from an Effective Field Theory Perspective* the authors start from the vantage point of effective field theories in theoretical physics. Such theories have been successfully used to provide a bottom-up description of phenomena whose intrinsic degrees of freedom behave at length scales far different from their effective degrees of freedom. As an example from the theory of quantum chromodynamics, Luu and Meißner focus on the behaviour of quarks and gluons and how they combine to form protons and neutrons or, collectively, nucleons, in order to justify an approach that moves from a fundamental description that makes use of quarks and gluons to an effective field theory description of nuclei. The length scales traversed by this explanation span at least two orders of magnitude. The authors thus provide an effective field theory viewpoint on the topic of emergence, arguing on the side of reductionism and weak emergence. The chapter closes with comments on Anderson's interpretation of constructionism and strong emergence and Ellis's antireductionist theory, which they criticise as non-falsifiable.

The third part of our collection, **The View from the Life Sciences**, explores the theory of top-down causation from the perspectives of physiology, biology and neuroscience. It presents three pieces, each operating on a different level.

The sixth chapter, by **Denis Noble**, is entitled *The Principle of Biological Relativity: Origins and Current Status* and has a particular significance: its topic, the biological relativity for which Noble is famous—among other notable contributions to medicine and biology, such as his mathematical model of the human heart—is inspired by his exchange with George Ellis. The chapter thus starts by outlining the origin story of the principle of biological relativity and its subsequent history. It was first formulated by distinguishing between the causal properties of initial and boundary conditions, regarded as a formal cause, as compared to the dynamics of the differential functions themselves, regarded as an efficient cause. The concepts of organisational level and of boundaries between levels and environmental factors are also central to the principle. Noble argues that work on the properties of boundaries reveals two important features: the nature of causation differs significantly between different levels of organisation, and the top-down and bottom-up forms must act

simultaneously. These developments of the principle are used to clarify the reasons why bottom-up causation alone is inadequate in multi-level biology.

The seventh chapter, by **Larissa Albantakis, Francesco Massari, Maggie Beheler-Amass** and **Giulio Tononi**, *A Macro Agent and its Actions*, draws on Ellis's theory to argue for an antireductionist account of causal interactions in complex, dynamical systems in general and in the case of autonomy and agency in particular. From the perspective of computational neuroscience, the authors argue (1) that agents require causal borders separating them from the environment which, in the context of biological agents, are (2) associated with complex, dynamical macro systems and (3) that such macro agents are supposed to act on their environment. As proponents of integrated information theory, the authors offer an antireductionist account of causation, specifically for the case of (neurological explanations of) agency. Albantakis, Massari, Beheler-Amass and Tononi demonstrate the framework of integrated information theory by using the example of a simulated agent equipped with a small neural network.

The eighth chapter, by **George F. R. Ellis**, is entitled *Physics, Determinism, and the Brain*. Here Ellis provides us with a deeper understanding of his account of how physics underlies the brain. Ellis begins by establishing the differences between synchronic and diachronic emergence in order to counter the idea that brain function is determined solely by microphysics in a bottom-up fashion. He then proceeds to spell out how his account of causation relates to the life sciences, especially biology and neuroscience, and gives arguments for understanding the brain as an open system. In doing so, he highlights the significance of diachronic emergence and brain plasticity. In the final paragraphs of the essay, Ellis discusses the role of randomness and its connection to agency and gives arguments pertaining to the idea of the causal closure of the universe and the topic of free will. The chapter thus provides not only new arguments defending Ellis's view of the brain against counterarguments, but also a detailed overview of his conception of the relationship between physics and the life sciences and how this bears on the connection between the human brain and the human mind.

The fourth part of this anthology **The Debate on Top-Down Causation and Emergence**, is dedicated to discussions of Ellis's theory in the context of surrounding debates on causation and emergence. It consists of five essays.

The ninth chapter, by **James Woodward**, entitled *Downward Causation Defended*, argues—as its title suggests—against certain lines of criticism directed at top-down/downward causation. Working from within the context of machine learning and computer science and drawing on work from Ellis and Noble, Woodward begins by offering the possibility of integrating his own interventionist account of causation with the aforementioned perspectives. He then illustrates the resulting philosophical account of top-down causation with the aid of examples from various sciences. The first widespread criticism Woodward refutes is that “wholes” cannot act downwardly on their “parts”, because the synchronous whole-part relationship is not a diachronic causal relationship. He then turns to other objections, such as causal exclusion arguments, by outlining the mistakes common to different forms of such arguments. Woodward does not limit himself to rebutting

these critiques: he goes on to sketch a more positive account of the work that can be done by the notion of downward causation.

The tenth chapter, by **Richard Healey**, is entitled *A Pragmatist Perspective on Causation, Laws and Explanation*. Working from a pragmatist perspective in the philosophy of science, it offers an explanation of how it is possible to abandon what he calls the Laplacean vision of causation, according to which the existence of global laws of nature determines the evolution of the world by determining the motion of its basic physical parts, in favour of a pragmatist understanding of (top-down) causation. For Healey, this goes hand in hand with a pragmatist conception of laws and explanation. As a consequence, he argues for a local understanding of causation, which does not reference any laws—contra the Laplacean vision—but focuses instead on the function played by the notions of causation, laws and explanation in our practical and theoretical undertakings. By looking at emergence and top-down causation through the lens of John Conway’s Game of Life, he argues that these notions are better suited to make sense of the phenomena when compared to the Laplacean vision of causation.

The eleventh chapter, by **Jan Voosholz**, entitled *Top-Down Causation Without Levels*, examines an apparent prerequisite of Ellis’s theory of top-down causation: the idea that nature is ordered by distinct and finitely many levels, each with their own types of entities, relations, laws and principles of behaviour as well as causal relations to their respective neighbouring top- and bottom-levels. Voosholz’s analysis of this “level-picture” of nature makes explicit certain key premises presupposed by this overall framework. He maintains that a closer examination of the relevant issues leads to two surprising conclusions: On the one hand, he argues that a potential critic of Ellis could attack the level-picture, exploiting its vulnerability to certain objections in order to refute the overall theory of top-down causation, genuine complexity and emergence. On the other hand, Voosholz’s investigation reveals that such a manoeuvre on the part the critic would ultimately prove futile. He shows that the theory can be defended by abandoning the level-picture and that adjusting certain important premises in light of the objections allows us to retain the key features of Ellis’s broader account.

The twelfth chapter, by **Simon Friederich** and **Sach Mukherjee**, is entitled *Causation as a High-Level Affair*. It argues against one of the most dominant reductionist arguments against accounts of top-down and higher-level causation, the causal exclusion argument, in favour of non-reductive physicalism as championed by Jaegwon Kim. The counterargument presented by the authors concludes that higher-level causation is a legitimate notion even if non-reductive physicalism holds; indeed, causal relations at the micro-physical level obtain either in a derivative sense, parasitic on higher-level causation, or are so dependent on background conditions as to dilute the term “causal”. This counterintuitive conclusion is supported by first summarising the interventionist response to this particular version of the causal exclusion argument and then focusing on how the difference between sensitive and insensitive background conditions allows the derivation of an argument for the robustness of higher-level causality. Finally, they show how this surprising outcome derives from the previous steps.

The thirteenth chapter, by **Max Kistler**, entitled *Models of Downward Causation*, takes on the causal exclusion arguments for physicalism and against any downward causation from the mind. His conclusion and solution diverges from Friederich's and Mukherjee's, yet he also argues for the possibility of downward causation. Kistler holds that we could not make sense of downward causation, especially from the mental and the abstract to the physical, in physicalist terms, because we have not yet found the right model for downward causation. In this chapter, Kistler now analyses two models of causal influences that provide this missing framework. The first model utilises the notion of phase space from dynamical systems theory. Kistler constructs such a model for a case of mental causation, showing that the causal exclusion arguments pose no threat and that downward causation is an unproblematic occurrence. The second model builds on the framework of structural equations which are used in the computer modelling of complex systems to find causal dependencies. Kistler argues that this model respects the principle of causal closure but the exclusion principle, the second premise of causal exclusion arguments, does not hold in this model. He concludes that in both models the exclusion premise is false and takes this as a sign that even physicalists should not endorse it.

In the fifth and final part of this Festschrift, **George F. R. Ellis** replies to each of the contributions in turn. In revisiting each chapter, he not only provides incisive and balanced responses to the assembled perspectives on his work, but also takes the opportunity to situate the multitude of issues that have been raised within a broader scientific and philosophical landscape.

We hope that readers will derive as much enlightenment from these contributions as we have and take them as an incentive to continue exploring the implications of George's unique work. It remains to express our thanks to everyone who has supported us during the process of editing this volume. Special thanks goes to Otávio Bueno, who has time and again—and with astonishing promptness—answered innumerable questions, and to Alex Englander, who has helped immensely with the revision of this introduction and provided frequent advise on our contributions. Finally, we would like to take this opportunity to congratulate you, George, on your birthday—we hope you will continue to provoke and inspire us for many years to come.

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