Chapter 1
A Framework for Mapping Mechanistic Perspectives

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This edited book is the outcome of a conference that was planned to take place in Lisbon at the Centro de Filosofia das Ciências (CFCUL) of the Faculdade de Ciências da Universidade de Lisboa. It was originally organized in the usual on-site form to which we were accustomed before the start of the Covid pandemic. The conference was postponed many times, with the hope to hold it on-site, to no avail. After many postponements, to our disappointment, the conference had unfortunately to be organized in a purely online form between 14th and 15th of October in 2021. The only advantage of all this is that we saved public money.

The eventual online conference was called *New Mechanism, Reduction and Emergence in Physics, Chemistry and Biology*. The participants were William Bechtel, Nancy Cartwright, Brigitte Falkenburg, Stuart Glennan, Robin Hendry, Alvaro Moreno and John Pemberton. Unfortunately, two of the talks (by Nancy Cartwright with John Pemberton and by Alvaro Moreno) did not result in a contribution to be published in the present volume. In the end, this book partially consists of a collection of articles based on some of the talks presented at the conference. Additionally, other contributions have been sought. It has not been easy at all to recruit other authors during the pandemic period. Our idea – already implicit in the conference title – was to seek contributions from research areas that have been somehow under-represented in the extant literature on new mechanism. We are therefore glad to have managed to enrol additional contributors, whose research encompasses several fields, including chemistry, biochemistry, developmental biology and ecology.

The idea for the conference originated from continuous conversations between its organizers, over many years, about the meaning of the qualification '*new*' in what is today generally called "new mechanism" in philosophy of science. One significant aspect of the conversation concerned the potential *limits* new mechanism

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faces when applied to areas of scientific research such as the quantum domain of physical reality, chemistry and biochemistry. Part of the rationale of the conference was thus to evaluate whether mechanistic analysis can be applied to sciences beyond those representing the original focus of new mechanism, particularly the molecular life sciences. An important caveat should be added at this juncture. Properly speaking, it is our contention that the advent of new mechanist perspectives in the twentieth century occurred simultaneously to the growing impact that cybernetics had, particularly on biology, after the late 1940s. By then, new mechanism was mainly seen as a way to overcome both old mechanist and neo-vitalist views. From the 1950s onwards, a variety of neo-mechanist approaches were developed (see Santos, Chap. 12 in this volume), the last of which being elaborated, from the 1990s, by the so-called "Chicago Mechanists"[1]. The fundamental difference of these latter neo-mechanist views is that they were articulated as a new breed of philosophy of science, tailored to stand in opposition to the nomological theory of explanation and the theory-reduction model promoted by neo-positivism. These developments eventually engendered a series of questions concerning the domain of applicability of the mechanistic approach as well as the necessity of revising – or even expanding – the nature of mechanist analysis in order to account for recalcitrant natural phenomena.

In general terms, the book addresses the epistemological and ontological significance of new mechanism and, in particular, its relationship with the topics of neo-mechanist explanation, emergence and reduction in the physical, chemical and biological sciences. Several particular questions are targeted in this book. For example, how many different types of mechanistic explanation can we distinguish and accommodate (Krickel)? Can, or even should, new mechanism engage with historically antagonist biological traditions (Bechtel and Bich)? Can mechanistic analysis encompass (or even encroach on) seemingly non-mechanistic explanatory practices (e.g., stemming from thermodynamics) not even aiming to structurally decompose phenomena (Vallejos and Vecchi)? Does new mechanism fit the phenomena studied by contemporary sciences such as quantum mechanics (Cordovil and Falkenburg), chemistry (Hendry and Scerri), biochemistry (Vallejos and Vecchi), evolutionary developmental biology (Villegas) or ecology (Martins)? What can the new mechanistic position on the ongoing debate about the different notions of reduction and emergence, either in ontological or epistemological terms, be (Cordovil, Glennan, Hendry, Santos, and Scerri)? The ultimate aim of this book is to contribute to critically evaluate the scope of new mechanism in all the above respects.

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In order to guide the reader, let us briefly elaborate on what should be considered the real *novelty* of any new mechanist perspective vis-à-vis the *old* seventeen-century mechanist philosophies. Paying attention to actual scientific practice is not a distinctive feature of new mechanism. Old mechanism was equally in tune with the

[1] Wimsatt, W. 2018. "Foreword", In S. Glennan and P. Illari (Eds.), *Routledge handbook of mechanisms and mechanical philosophy* (pp. xiv–xvi). New York: Routledge.

scientific practice of its time. Moreover, attention to actual scientific practice is pervasive in serious history and philosophy of science, including the often-disparaged analyses of the neo-positivists. Given the different versions of the mechanistic perspective paving the history of philosophy and science, including the different *neo*-mechanist approaches emerging in the twentieth century, it might indeed be wondered whether there is anything distinctive constituting the theoretical core of any mechanistic view about the world. We would synthetize the core of old mechanistic philosophy in the following six features. **First**, mechanism postulates a pluralistic ontology of ontically discontinuous and discernible entities, even if spatially contiguous. In this sense, mechanism opposes absolute monism. **Second**, mechanism argues for the ontological and epistemological priority of *causal* relations and explanations. In this sense, mechanism opposes what would become radical empiricism and neo-positivism. **Third**, mechanism postulates the exclusive existence of *local* causal relations, either by direct contiguity or by propagation through a medium, therefore denying unmediated relations at a distance (which justifies Newton's problematic relation with his own theory of gravity as well as the contemporary problems mechanism encounters in accounting for phenomena such as quantum entanglement). **Fourth**, mechanism contends that, through their causal relations, entities form part-whole relations. In this sense, mechanism opposes mereological nihilism. **Fifth**, mechanism characterizes, as fundamental explanatory steps, the analytical tasks of decomposition and localization and the synthetic task of recomposition. **Sixth**, mechanism recognizes and highlights the existence of universal laws, causal or otherwise, expressible in mathematical terms.

While this characterization of the theoretical core of the old or original mechanistic view is not exhaustive, it remains useful to map the diversity of extant mechanistic approaches. More significantly, our characterization might be instrumental to identify the epistemological and ontological commitments of different versions of mechanism. Concerning the first and fifth features, mechanistic approaches might vary in recognizing the limitations of the analytic tasks of localization and decomposition; when failure of localization and/or decomposition rules, mechanistic analysis might be complemented by different analytic strategies (e.g., network analysis, dynamic systems theory, computational analysis, thermodynamic approaches). Whether these additional strategies might be considered mechanistic is under dispute, especially when they do not explicitly aim to open black boxes. Concerning the second feature, mechanistic approaches might vary in taking into consideration varieties of causal relations, with a basic opposition between those approaches privileging (or even merely countenancing) linear or additive relations and those encompassing non-linear and non-additive relations. Furthermore, mechanistic approaches might vary in relation to the nature of the kinds of changes that causal relations bring about in their relata (i.e., whether merely quantitative, qualitative and even substantial, that is, of kind). Mechanistic approaches might also vary in their implicit commitments to alternative ontologies, with the contrast between atomist/individualist essentialism and relationalism coming to the fore. Concerning the fourth feature, mechanistic approaches might vary in terms of endorsing or not an exclusive bottom-up or parts-to-whole ontological determination, without considering the

reversal form of partial and complementary, systemic co-determination. Correlatively, they also might vary in considering their ultimate aim as a whole-to-part reductive explanation. Relatedly, and concerning the fifth feature, mechanistic approaches might also vary concerning the necessity of including the additional synthetic task of (environmentally, contextually) "situating" when providing the explanation of any mechanism or system's behaviour, thereby acknowledging the importance of not falling back into the classical isolated system view. Finally, mechanistic approaches might vary in terms of the relative epistemological role given to laws or law-like generalizations in the construction of science and scientific explanations, emphasizing instead the discovery of local mechanisms (this latter being a characteristic feature of the so-called "Chicago mechanism"). An additional distinctive feature would consist in defending the existence of different emergent laws and regional ontologies at different levels of organization or spatial-temporal scales. We would surmise that this minimal framework for mapping mechanistic perspectives might be helpful to navigate the ensuing contributions.

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Let us finally introduce the themes of the book's contributions and justify their sequential order. The first contribution, by Beate Krickel, deals with the nature of mechanistic explanation. As she argues, the assumption that there are just two kinds (i.e., *etiological* and *constitutive*) of mechanistic explanations is too narrow. Krickel therefore provides a quadripartite taxonomy, with two variants of etiological explanation—which she calls *output mechanistic explanations* and *input-output mechanistic explanations*—and two variants of constitutive explanation—which she calls *filler mechanistic explanations* and *dimensioned mechanistic explanations*. Krickel then delves on the differences between the two kinds of constitutive explanations, particularly in relation to the issues of reduction, mechanistic level and interlevel causation. The following eight contributions are focused on particular research fields. We have decided to organize them in a sequential order that some readers might considered topsy turvy, from ecology to physics, in descending order of system's complexity (in the minimal sense of number and kinds of system's parts and number and kinds of their interactions). We do not see any good reason to use the other sequential order. Gonçalo Martins focuses on mechanistic accounts in ecology, an area of research neglected in the extant mechanistic literature. Martins critically analyses the Metabolic Theory of Ecology. As its name suggests, this theory aims to account for population, community and ecosystem phenomena in terms of individual organisms' metabolism. Martins acknowledges that the metabolic theory provides significant explanations of some phenomena at various levels of ecological organization. Nevertheless, he also argues that, first, the mechanistic nature of this approach needs further clarification and, secondly, that the metabolic theory is not able to completely elucidate the mechanistic basis of the ecological phenomena it explains. Cristina Villegas centres her analysis on evolutionary developmental biology (evo-devo), a field of research that features slightly more prominently than ecology in the extant mechanistic literature. This field is peculiar because practitioners often describe their explanations as mechanistic. It is also peculiar because, like

ecology, evolutionary issues are central. Villegas' aim is to provide a philosophical framework to make sense of the causal role of developmental processes in evolution. She therefore analyses the prospects and limits of a mechanistic view of evo-devo focusing on studies of homology and novelty. Finally, Villegas suggests a way to combine the mechanistic view of evo-devo with the population-level analysis of classical approaches to evolution. Next in the sequence is the contribution by William Bechtel and Leonardo Bich. This paper prolongs the effort to expand the classical version of Chicago's new mechanism by promoting a constructive engagement with the autonomy tradition centred on organismal self-maintenance. Bechtel and Bich argue that a natural linkage between these two traditions is given by the fact that self-maintenance relies on mechanisms. What the autonomy tradition adds to this picture is the notion of control, which in its turn implies, Bechtel and Bich argue, characterizing mechanisms as sets of constraints on the flow of free energy. The relationship between control and controlled mechanisms is, they finally argue, heterarchical. In their contribution, Vallejos and Vecchi analyse two different biochemical approaches to the protein folding problem: kinetic approaches are intuitively mechanistic, aiming to reconstruct folding pathways in terms of structural considerations; thermodynamic approaches instead focus on energetic considerations, neglecting structural changes. After briefly illustrating the origin of these alternative approaches, Vallejos and Vecchi characterise their contrasting epistemological and ontological commitments. They then critically analyse in what sense thermodynamic explanations of folding might be said to be mechanistic or causal. The underlying issue – implicit in Bechtel and Bich's as well as Hendry's and Scerri's contributions – concerns the possibility of meaningfully combining thermodynamic and mechanistic analyses. Robin Hendry centres his analysis on the nature of reaction mechanisms in chemistry. Mechanistic explanations of chemical reactions are – as Vallejos and Vecchi relate in the case of biochemistry – kinetic in nature. These explanations aim to identify significant chemical pathways, decomposing them into a series of steps involving structural modifications such as the breaking and making of bonds. The problem Hendry addresses is whether the establishment of a reaction mechanism vindicates the reduction of chemistry to physics. Hendry argues that, while in a sense this might be considered the case (chemical processes basically involve transfers of conserved quantities), in another sense, arguably more significant, reduction is not vindicated. Eric Scerri's contribution aims to critically evaluate some of Hendry's arguments in support of emergence and downward causation in chemistry as well as on the nature of the chemical bond. In the first sense, Scerri argues that alternative explanations (e.g., based on the notion of quantum decoherence) of the compositional identity but structural difference of isomers make emergence and downward causation redundant. In the second sense, Scerri points again at the structural vs. thermodynamic contrast underlying the chemical sciences. In particular, he argues that, while it is true that chemists view bonding in a more realistic fashion while physicists consider bonding in more abstract energetic terms, such differences in scientific practice do not substantiate specific views about the ontological status of bonding. João L. Cordovil's contribution argues that the challenges posed by Quantum Mechanics to mechanism are not

substantially new, since there has always been a problematic relationship between mechanical philosophy and fundamental physics throughout the history of physics. Despite this, mechanism always prevailed. According to Cordovil, although fundamental physics may not be compatible with new mechanism, this incompatibility can only be considered as a fundamental problem if we uphold the micro-physicalist assumption concerning the universal character of quantum mechanics. Cordovil thus suggests that, rather than trying to find an answer to this problem in the quantum decoherence hypothesis, it would be better to consider the ways in which the classical physical domain might have emerged from the quantum domain of physical reality. In her contribution, Brigitte Falkenburg argues that, notwithstanding the scientific revolutions of the twentieth century, mechanistic approaches continue to be based on the traditional method of analysis and synthesis and, therefore, on the assumption that all higher-level phenomena are to be explained in terms of lower-level parts' properties, their interactions, and some composition rules. Nevertheless, quantum fields, as well as higher-level phenomena (e.g., chemical, biochemical, and biological) pose challenges to the mechanistic approach. Thus Falkenburg asks: is it just a mere *façon de parler* to talk of mechanisms underlying such phenomena? In particular, Falkenburg points out, no mechanism is known that might explain how the brain produces the conscious human mind. The last two chapters focus on the topic of emergence and its relationship with the mechanistic approach. In his contribution, Stuart Glennan aims to show that the opposition between mechanism and emergence is essentially based on a misunderstanding and that the core features of emergent phenomena (dependence, autonomy, holism and novelty) can be explicated in mechanistic terms. Indeed, according to Glennan, if there are naturalistic processes of emergence there must be mechanisms responsible for their existence. Furthermore, the mechanistic view allows the possibility of classifying different kinds of emergent phenomena in terms of the particular features of the mechanisms generating them. For example, the distinction between mechanisms that produce phenomena vs. mechanisms that underlie phenomena provides an analysis of the distinction between diachronic and synchronic emergence, and various interpretations of novelty, holism and autonomy can then be shown to arise from different kinds of mechanistic organization. Gil Santos' contribution proposes a dynamic relational account of both systemic emergence and downward causation. In particular, Santos argues for a relational-transformational notion of emergence and a structural-relational account of downward causation in terms of both its transformational and conditioning effects. According to Santos, it is the objective existence of systemic emergence and downward-structural causation that ultimately justifies the in-principle failure of any form of micro-determinism and micro-reductionism, and that at the same time most strongly requires the use of interlevel integrative forms of explanation. Furthermore, according to the author, it is here that one may find the real ontological and epistemological novelty of any neo-mechanistic view in comparison to the old seventeenth-century mechanicist philosophies. We wish you an enjoyable read.

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