European Studies in Philosophy of Science

Brigitte Falkenburg
Gregor Schiemann *Editors*

Mechanistic Explanations in Physics and Beyond

Springer

European Studies in Philosophy of Science

Volume 11

This new series results from the synergy of EPSA - European Philosophy of Science Association - and PSE - Philosophy of Science in a European Perspective: ESF Networking Programme (2008–2013). It continues the aims of the Springer series "The Philosophy of Science in a European Perspective" and is meant to give a new impetus to European research in the philosophy of science. The main purpose of the series is to provide a publication platform to young researchers working in Europe, who will thus be encouraged to publish in English and make their work internationally known and available. In addition, the series will host the EPSA conference proceedings, selected papers coming from workshops, edited volumes on specific issues in the philosophy of science, monographs and outstanding Ph.D. dissertations. There will be a special emphasis on philosophy of science originating from Europe. In all cases there will be a commitment to high standards of quality. The Editors will be assisted by an Editorial Board of renowned scholars, who will advise on the selection of manuscripts to be considered for publication.

More information about this series at http://www.springer.com/series/13909

Brigitte Falkenburg • Gregor Schiemann
Editors

Mechanistic Explanations in Physics and Beyond

Springer

AIPS

Editors
Brigitte Falkenburg
Technische Universität Dortmund
Dortmund, Germany

Gregor Schiemann
Bergische Universität Wuppertal
Wuppertal, Germany

ISSN 2365-4228 ISSN 2365-4236 (electronic)
European Studies in Philosophy of Science
ISBN 978-3-030-10706-2 ISBN 978-3-030-10707-9 (eBook)
https://doi.org/10.1007/978-3-030-10707-9

This Springer imprint is published by the registered company Springer Nature Switzerland AG.
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Mechanistic explanations explain how certain properties of a whole stem from the causal activities of its parts. In the practice of science, many explanatory models of complex systems and their behaviour employ this kind of explanation. Given that mechanistic explanations are widely spread in biology and neuroscience, the philosophy of biology and neuroscience took them up, giving rise to an extended philosophical debate on the structure and scope of mechanistic explanations. With this book, we want to broaden the scope of the discussion, going back to the roots of mechanistic explanations in physics.

The book emerged from the 2016 conference *Mechanistic Explanations, Computability and Complex Systems* of the *Académie Internationale de Philosophie des Sciences (AIPS)*, which took place at the Technische Universität Dortmund, October 28–30, 2016. The *AIPS*, the *German Research Foundation (DFG)*, and the *Society of the Friends of the Technische Universität Dortmund* generously supported the conference. Without the endorsement of the president of the *AIPS*, Gerhard Heinzmann, it would not have been possible to organize the conference and to edit this book. The book chapters emerged from the talks given at the conference, except Meinard Kuhlmann's whom we invited afterwards to contribute to the volume. In addition, we would like to thank the editors of the European Studies in Philosophy of Science, Dennis Dieks, Maria Carla Galavotti, and Wenceslao J. Gonzalez, for the possibility of publishing the book in this series. We wish to express our gratitude to Stuart Glennan for his valuable comments on the contributions to this volume.

Dortmund, Germany	Brigitte Falkenburg
Wuppertal, Germany	Gregor Schiemann
January 2018	

Contents

Chapter 1
Introduction

Brigitte Falkenburg and Gregor Schiemann

1.1 Relation to New Mechanism

Biological and neuroscientific phenomena are in the fore of works on new mechanism – a dominance that may have emerged for historical, contingent reasons. New mechanism justifiably criticized the so-called covering law model of explanation as it overly relies on physical theories and is applicable to biological phenomena only to a limited extent, at best. According to the covering law model, a phenomenon is considered explained when its theoretical representation is deductively derived using a law of nature. However, whether there are any biological laws at all is a problematic issue. Despite its focus on physical theories, the influential covering law model was also subject to criticism as it did not do justice to the explanations and models of physical practices. The notion of natural law remained in need of clarification; commonly occurring statistical explanations were not strictly necessary; in the formal representation cause and effect of phenomena were interexchangeable – only to mention a few well-known issues with the use of the covering law model in physics.

As of yet, new mechanism impulses have been only partially absorbed into the philosophy of physics. Examples of an absorbed integration of new mechanism in the scientific theory of physics are: Illari and Williamson (2012), Kuhlmann and Glennan (2014) and Kuhlmann (2017). Even more astounding when one considers that throughout history, mechanistic explanations have been closely bound to physics, and that contemporary physics is rife with mechanistic explanations, often

B. Falkenburg (✉)
Technische Universität Dortmund, Dortmund, Germany
e-mail: brigitte.falkenburg@tu-dortmund.de

G. Schiemann
Bergische Universität Wuppertal, Wuppertal, Germany
e-mail: schiemann@uni-wuppertal.de

B. Falkenburg, G. Schiemann (eds.), *Mechanistic Explanations in Physics and Beyond*, European Studies in Philosophy of Science 11,
https://doi.org/10.1007/978-3-030-10707-9_1

explicitly using the term "mechanism" (see the examples given in Falkenburg's contribution. In the following, all citations without year refer to the contributions of this volume). New mechanism offers a conceptual instrumentation for a better understanding of these points of contact. On the other hand, an increased reference to physical phenomena within the mechanistic explanation discussion, to which this volume would like to contribute, will provide a new historic and systematic gain of knowledge regarding new mechanism. Thus, for example, reflecting on new mechanism's historical origins can be beneficial in clarifying its contemporary conceptual issues (for a paradigmatic example see Glennan 1992). Furthermore, as explanations in terms of levels, mechanistic explanations draw from the underlying physical conditions and processes of complex phenomena. The discussion surrounding the scope of mechanism can therefore not succeed without taking the physical foundations into account. Finally, the comprehensive claim of validity of new mechanism requires the most all-encompassing inclusion of physics.

Increasingly recognizing physical phenomena as components of mechanistic explanations triggers questions concerning the general structure of mechanistic explanations; concerning the conditions under which other sciences explain complex phenomena by drawing on physical conditions and processes; as well as questions concerning the possibilities of mechanism of computation, which are closely related to mathematical theories.

1.2 Structure and Scope of the Book

We divided the book into three parts. *Part I* is made up by four chapters that compare the traditional mechanical explanations of early modern science and philosophy to the current accounts of mechanistic explanations. The three chapters of *Part II* deal with general questions concerning the relations between mechanisms, causality, and the multi-level structure of complex systems in physics and beyond. Finally, *Part III* collects three studies that investigate the scope of mechanistic explanations in different sciences, making the bridge from physics to economics, complexity and computation theory.

A general topic of the book is the question of how current mechanistic explanations in physics and beyond relate to the roots of mechanical explanations in early modern science and philosophy. Are current mechanistic explanations legitimate successors of their early modern precursors or not? To what extent does it make sense to generalize the traditional mechanical explanations? The four chapters of *Part I* investigate these questions going back to traditional accounts of mechanical explanations, whereas the chapters of *Part III* provide case studies from the practice of science in order to shed light on the scope of mechanistic explanations.

In addition, the contributions to the book address three groups of crucial metaphysical questions. (i) What is the ontological and/or epistemological import of mechanistic explanations, and what is their methodological significance within the practice of science? (ii) How do the causal aspects of mechanisms relate to the laws of physics? (iii) How does theory reduction relate to ontological reduction, to what extent can mechanisms explain the emergence of higher-level phenomena in nature? Here, the compositional complexity of mechanisms comes into play, and in particular, the one-level or multi-level structure of mechanisms. The three chapters of *Part II* focus on these metaphysical problems, which however also are important side issues of the contributions to *Parts I* and *III*.

Obviously, the scope of mechanistic explanations crucially depends on the respective definition of a mechanism and its interpretation. The concepts of mechanisms underlying the book contributions, however, are not uniform. Almost all book chapters rely on the seminal definitions of Glennan (1996, 2002) and Machamer et al. (2000). However, they interpret the metaphysical implications of these definitions in different ways. The ways in which they relate them to their traditional precursors neither are uniform. The differences begin with the historical background sketched in the chapters of *Part I*.

1.2.1 Part I: Mechanisms in History and Today

The four chapters of *Part I* focus on the tradition of mechanistic explanations in physics. They substantially differ in the underlying traditional concepts of a mechanism as well as in the systematic aspects of mechanistic explanations they study, complementing each other nicely regarding the metaphysical and methodological aspects of mechanistic explanations. – In *Mechanisms, Then and Now: From Metaphysics to Practice*, Stathis Psillos and Stavros Ioannidis base their discussion on Descartes' mechanistic model of matter. In contradistinction to it, they consider Newton's theory of gravitation as critical of mechanism. On these grounds, they discuss the distinction of mechanism as a metaphysical thesis and as a methodological principle of scientific theories, concluding with a plea for methodological mechanism. – For Gregor Schiemann, the traditional account of a mechanism relies on the Post-Cartesian concepts of matter in motion as described by mechanics. His chapter *Old and New Mechanistic Ontologies* compares monistic and dualistic ontologies of matter and force, as represented by Huygen's and Newton's theories. Against this metaphysical background, he interprets Glennan's account of a mechanism as monistic, but the one of Machamer, Darden and Craver as dualistic. – In *Mechanisms, Explanation and Understanding in Physics*, Dennis Dieks emphasizes that mathematization is much more typical of the explanatory tradition of physics than mechanization. His starting point is a concept of mechanism (following Psillos 2011), according to which (spatial) decomposition characterizes a mechanism. He argues that classical physics does not commit to mechanistic explanations, given that there are alternatives to a Newtonian perspective on classical mechanics and to the mechanical models of Maxwell's electrodynamics. In addition, he shows that quantum mechanics is at odds with his account of a mechanism. – In *Mechanistic Explanations Generalized: How Far Can We Go?* Brigitte Falkenburg takes the seventeenth century concept of a machine as underlying. Her chapter investigates the methodological and ontological continuity of mechanistic explanations from early modern science to current scientific practice, focusing on their generalizations in physics. She discusses how they fit in with a generalized mechanistic methodology of the "dissecting" sciences, on the one hand, and philosophical generalizations of the concept of a mechanism, on the other hand.

1.2.2 Part II: Mechanisms, Causality, and Multilevel Systems

The chapters collected in *Part II* tackle systematic questions concerning mechanistic explanations. Their common topic is the role of causality in mechanistic explanations and the way in which it relates to the distinction between higher-level and lower-level mechanisms. – Michel Ghins proposes in *Mechanist Explanation: An Extension and Defence* an enlarged version of the mechanistic account of explanation, advocated by Wesley Salmon and Phil Dowe. This avoids a problematic dichotomy between mechanistic causality and fundamental causality. Furthermore, its scope of application comprises explanations of the global behaviour of complex systems, not only in physics but also in all other scientific fields. – In *Multilevel Reality, Mechanistic Explanations, and Intertheoretic Reduction*, Marco Buzzoni counters the view that questions regarding the nature of *interlevel* explanations may be addressed separately from the *intertheoretic* reduction issue. Under the assumption that mechanistic explanations depend on perspectives, which scientists explicitly or implicitly adopt, interlevel explanations and intertheoretic reductions become connected. Buzzoni introduces an ideal distinction between weak and strong relations of perspectives in order to clarify the connection. Weak relations are combined with compatible theories, strong relations with incompatible theories. Examples taken from physics, biology and cancer research demonstrate that successfully interconnecting multiple perspectives makes the development of new perspectives necessary. – With his *A Methodological Interpretation of Mechanistic Explanation,* Hans Lenk relates several current causal and mechanistic explanation approaches to his scheme-interpretationism. This methodological approach presented in several publications (e.g. Lenk 2003) comprises the philosophy of knowledge and of action. Lenk's view that grasping cognition und action depend on interpretation exhibits partial similarity to Buzzonis perspectivalism. More generally speaking, several beneficial relationships exist between methodological scheme-interpretationism and new mechanism.

1.2.3 Part III: From Physics to Complexity and Computation

The three chapters of *Part III* investigate the scope of mechanistic explanations in the theory of complex systems, economics, and computer science. One of them is critical of the new mechanical philosophy. The other two demonstrate physics-based applications of mechanistic explanations beyond physics.– Jan Faye's contribution *Causal Mechanisms, Complexity, and the Environment* suggests abandoning the vertical top-down and bottom-up models of mechanisms in favour of a horizontal perspective on the interaction of complex systems with their environment, in order to avoid the dilemma of either downward causation or epiphenomenalism in mechanistic explanations of emergent phenomena. According to this horizontal perspective, the properties of a complex system such as the behaviour of a flock of starlings are due to external properties of the stars. – In *Crossing Boundaries: Why Physics Can Help Understand Economics*, Meinard Kuhlmann shows how the mechanisms of condensed matter physics apply to economics due to formal analogies between the macro-behaviour of social collectives and complex many-particle systems, which gave rise to the discipline of econophysics. He discusses the analogy between critical phase transitions and financial market crashes and claims that the models of econophysics describe causal mechanisms. – The chapter *Realizing Computations* of Vincenzo Fano, Pierluigi Graziani, Mirko Tagliaferri, and Gino Tarozzi completes the book. They develop a philosophical notion of the implementation of a computation, according to which by a physical system realizes a computation if there is a map from the computational states to a discrete model of system. Their definition of implementation helps understanding the mechanisms of computation, given that it explains the phenomenon of computation in terms of the (modelled) parts of a physical system individuated by the implementation function they suggest.

1.3 Concluding Remarks

The question of how strict or liberal mechanistic explanations should be understood remains open and controversial. This holds for mechanisms in general as well as in particular to their application to physical phenomena. Nevertheless, it is possible to state some tendencies. In the context of the general discussion, which focuses on the practice of biological and neuroscientific research, a broad minimal definition of the mechanism has gained in importance (Craver and Tabery 2015; Glennan and Illari 2017). In view of the physical phenomena that dominated the history of the mechanism, and that still represent a great potential for applying it today, differences in defining the scope of the concept remain significant. Historical ways of understanding that go back to the early modern period (Dieks, Falkenburg, Psillos and Stavros, Schiemann) differ from opinions that refer to the practice of current physics and its applications in other disciplines (Falkenburg, Ghins, Kuhlmann). Last not least, the authors disagree on the question of whether or not quantum mechanisms exist (Dieks vs. Kuhlmann and Glennan 2014).

However the term is understood, it must do justice to the many facets of mechanistic explanations. The actually existing plurality of phenomena (Buzzoni, Dieks, Falkenburg, Faye, Psillos and Stavros) is in tense relationship with well-justified methodological claims of universality (Buzzoni, Falkenburg, Ghins, Kuhlmann).

The universality of mechanistic models works best in cases of formal analogies (Faye, Kuhlmann) or in cases of computer algorithms that can be mapped to idealized models of physical systems (Fano).

Relatively independent of the respective concept, the authors of our volume broadly agree that the potential for applying the notion of mechanistic explanations to physical phenomena is by no means exhausted, however probably limited. The concept of mechanistic explanations serves for an understanding with intuitive models (Dieks), but also opens ways for general insights of how to decompose natural phenomena into dynamic part-whole relations between complex systems and their dynamic parts (Falkenburg). The limitations of applying a mechanistic approach in the most general sense to complex phenomena show up in diverse fields of physics, and in particular at the level of the fundamental laws of quantum mechanics and relativity theories (Dieks; Glennan 1996). By discussing cases of how the concept of mechanistic explanations applies to physical phenomena, approaches can be developed which are also fruitful for the subject areas of other disciplines (Buzzoni, Fano, Ghins, Kuhlmann).

For the discussion of mechanistic explanations in the philosophy of physics, the significance of ontological questions is perhaps just as disputed as in the general discourse of the mechanism. Ontological questions relating to the existence and structure of objects play a particular role with regard to multilevel explanations, in which physical phenomena constitute the lower layer used to explain the more complex phenomena of the upper layers. Do elements of these structures exist independently of the way in which science captures them, or are they primarily due to the theoretical assumptions underlying the access to them by science? Relying on different aspects of the practice of physics, the importance of ontology is either relativized (Lenk, Psillos and Stavros), or emphasized (Falkenburg, Faye, Schiemann).

With regard to the theories of explanation developed in the philosophy of science in physics, the mechanistic approach is only able to cope with a subdomain (Dieks, Falkenburg). In spite of its explanatory limitations, however, the innovative and by no means sufficiently recognized potential of the new mechanism for the philosophy of physics should not be underestimated. After a still unfinished phase of demarcating the new mechanism against the philosophy of physics, which is due to the criticism of the Covering-Law model of explanation, we hope that in the future the mechanistic explanations of physics will once again contribute to stimulating the general discussion about mechanisms.

References

Craver, C.F., and J. G. Tabery. 2015. Mechanisms in Science. In *Stanford Encyclopedia of Philosophy*, ed. E.N. Zalta. https://plato.stanford.edu/entries/science-mechanisms [07.04.2017].

Glennan, S.S. 1992. *Mechanisms, Models, and Causation*. Ph.D. dissertation. University of Chicago, Chicago, IL.

———. 1996. Mechanisms and the Nature of Causation. *Erkenntnis* 44 (1): 49–71.

———. 2002. Rethinking Mechanistic Explanation. *Philosophy of Science* 69 (S3): 342–353.

Glennan, S.S., and P. Illari. 2017. Varieties of Mechanisms. In *The Routledge Handbook of Mechanisms and Mechanical Philosophy*, ed. S. Glennan and P. Illari, 91–103. New York: Routledge.

Illari, P., and J. Williamson. 2012. What Is a Mechanism? Thinking About Mechanisms 'Across' the Sciences. *European Journal for Philosophy of Science* 2 (1): 119–135.

Kuhlmann, M. 2017. Mechanisms in Physics (with an Enhanced Bibliography). In *The Routledge Handbook of Mechanisms and Mechanical Philosophy*, ed. S. Glennan and P. Illari, 283–295. New York: Routledge.

Kuhlmann, M., and S.S. Glennan. 2014. On the Relation Between Quantum Mechanical, and Neo-Mechanistic Ontologies and Explanatory Strategies. *European Journal for Philosophy of Science* 4: 337–359.

Lenk, H. 2003. *Grasping Reality*. Singapore: World Scientific.

Machamer, P., et al. 2000. Thinking About Mechanisms. *Philosophy of Science* 67 (1): 1–25.

Psillos, S. 2011. The Idea of Mechanism. In *Causality in the Sciences*, ed. P. McKay, F. Russo, and J. Williamson, 771–788. Oxford: Oxford University Press.

Part I
Mechanisms in History and Today

Chapter 2
Mechanisms, *Then and Now:* From Metaphysics to Practice

Stathis Psillos and Stavros Ioannidis

Abstract For many old and new mechanists, Mechanism is both a metaphysical position and a thesis about scientific methodology. In this paper we discuss the relation between the metaphysics of mechanisms and the role of mechanical explanation in the practice of science, by presenting and comparing the key tenets of Old and New Mechanism. First, by focusing on the case of gravity, we show how the metaphysics of Old Mechanism constrained scientific explanation, and discuss Newton's critique of Old Mechanism. Second, we examine the current mechanistic metaphysics, arguing that it is not warranted by the use of the concept of mechanism in scientific practice, and motivate a thin conception of mechanism (the truly minimal view), according to which mechanisms are causal pathways for a certain effect or phenomenon. Finally, we draw analogies between Newton's critique of Old Mechanism and our thesis that the metaphysical commitments of New Mechanism are not necessary in order to illuminate scientific practice.

2.1 Introduction

The mechanical worldview of the seventeenth century was both a metaphysical thesis and a scientific theory. It was a metaphysical thesis insofar as it was committed to a reductionist account of all worldly phenomena to configurations of matter in motion subject to laws. In particular, it was committed to the view that all macroscopic phenomena are caused by, and hence are accounted for, the interactions

S. Psillos (✉) · S. Ioannidis
Department of History and Philosophy of Science, University of Athens, Athens, Greece
e-mail: psillos@phs.uoa.gr; sioannidis@phs.uoa.gr

B. Falkenburg, G. Schiemann (eds.), *Mechanistic Explanations in Physics and Beyond*, European Studies in Philosophy of Science 11,
https://doi.org/10.1007/978-3-030-10707-9_2

of invisible microscopic material corpuscles. Margaret Wilson captured this view succinctly:

> The mechanism characteristic of the new science of the seventeenth century may be briefly characterised as follows: Mechanists held that all macroscopic bodily phenomena result from the motions and impacts of submicroscopic particles, or corpuscles, each of which can be fully characterised in terms of a strictly limited range of (primary) properties: size, shape, motion and, perhaps, solidity and impenetrability (1999, xiii–xiv).

But this metaphysical thesis did, at the same time, license a scientific theory of the world, viz., a certain conception of scientific explanation and of theory-construction. To offer a scientific explanation of a worldly phenomenon X was to provide a configuration Y of matter in motion, subject to laws, such that Y could cause X. A mechanical explanation then was (a species of) *causal explanation*: to explain that Y causes X was tantamount to constructing a mechanical model of how Y brings about X. The model was mechanical insofar as it was based on resources licensed by the metaphysical worldview, viz., action of particles by contact in virtue of their primary qualities and subject to laws of motion.[1]

Nearly four centuries later, the mechanical worldview has become prominent again within philosophy of science. It's become known as 'the New Mechanical Philosophy' and has similar aspirations as the old one. New Mechanism, as Stuart Glennan puts it,

> says of nature that most or all the phenomena found in nature depend on mechanisms—collections of entities whose activities and interactions, suitably organized, are responsible for these phenomena. It says of science that its chief business is the construction of models that describe, predict, and explain these mechanism-dependent phenomena (2017, 1).

So, New Mechanism too is both a view about science *and* about the metaphysics of nature. And yet, in New Mechanism the primary focus has been on scientific practice, and in particular on the use of mechanisms in discovery, reasoning and representation (cf. Glennan 2017, 12). The focus on the metaphysics of mechanisms has emerged as an attempt to draw conclusions about the ontic signature of the world starting from the concept of mechanism as it is used in the sciences. According to Glennan, as the research into the use of mechanism in science developed, "it has been clear to many participants in the discussion that metaphysical questions are unavoidable" (2017, 12). It is fair to say that New Mechanism aims to ground the metaphysics of mechanisms on the practice of mechanical explanation in the sciences.

The chief aim of this paper is to discuss the relation between the metaphysics of mechanisms and the role of mechanical explanation in the practice of science. It will do that by presenting and comparing the key tenets of Old and New Mechanism. Section 2.2 will be devoted to the seventeenth century Mechanism. It will present the basic contours of the mechanistic metaphysics and show how it constrained scientific explanation, focusing on the case of gravity. In this section, we will also

[1] For the purposes of this paper, we ignore issues of mind-body causation and we focus on body-body causation. We also ignore divisions among mechanists concerning the nature of corpuscles, the existence of vacuum etc.

discuss Isaac Newton's critique of mechanism and highlight the significance of his key thought, viz., that causal explanation should identify the causes and the laws that govern their action, irrespective of whether or not these causes can be taken to satisfy certain (mostly metaphysically driven) constraints, such as being modelled in terms of configurations of matter in motion. Section 2.3 will focus on the current mechanistic metaphysics and show that it is not warranted by the use of the concept of mechanism in scientific practice. It will show that the currently popular minimal general characterisation of a mechanism is still metaphysically inflated in various ways and will motivate a thin conception of mechanism, which is not committed to any views about the ontological signature of mechanism. This thin conception—what we call 'truly minimal mechanism'—takes it that mechanisms are causal pathways for a certain effect or phenomenon. Finally, in Sect. 2.4 we will draw analogies between Newton's critique of Old Mechanism and our critique of New Mechanism. Briefly put, the point will be that causal explanation in the sciences is legitimate even if we bracket the issue of "what mechanisms or causes are as things in the world" (Glennan 2017, 12); or the issue of what activities are and how they are related to powers and the like. The metaphysical commitments of New Mechanism are not necessary in order to illuminate scientific practice.

2.2 Old Mechanism: From Metaphysics to Practice

A rather typical example of the interplay between the metaphysical worldview and the scientific conception of the world in the seventeenth century was the attempted mechanical explanation of gravity.

2.2.1 Mechanical Models of Gravity

Let us start with René Descartes. The central aim of the 3rd and 4th part of Descartes's *Principia Philosophiae*, published in 1644, was the construction of an account of natural phenomena. In Cartesian physics, the possible empirical models of the world are restricted from above by a priori principles which capture the fundamental laws of motion and from below by experience. Between these two levels there are various theoretical hypotheses, which constitute the proper empirical subject-matter of science. These are mechanical hypotheses; they refer to configurations of matter in motion. As Descartes explains in (III, 46) of the *Principia*, since it is a priori possible that there are countless configurations of matter in motion that can underlie the various natural phenomena, "unaided reason" is not able to figure out the right configuration of matter in motion. Mechanical hypotheses are necessary but experience should be appealed to, in order to pick out the correct one:

> [W]e are now at liberty to assume anything we please [about the mechanical configuration], provided that everything we shall deduce from it is {entirely} in conformity with experience (III, 46; 1982, 106).

These mechanical hypotheses aim to capture the putative causes of the phenomena under investigation (III, 47). Hence, they are explanatory of the phenomena. Causal explanation—that is, mechanical explanation—proceeds via decomposition. It is a commitment of the mechanical philosophy that the behaviour of observable bodies should be accounted for on the basis of the interactions among their constituent parts and particles; hence, on the basis of unobservable entities. In (IV, 201; 1982, 283), Descartes states that sensible bodies are composed of insensible particles. But to get to know these particles and their properties a *bridge principle* is necessary; that is, a principle that connects the micro-constituents with the macro-bodies. According to this principle, the properties of the minute particles should be modelled on the properties of macro-bodies. Here is how Descartes put it:

> Nor do I think that anyone who is using his reason will be prepared to deny that it is far better to judge of things which occur in tiny bodies (which escape our senses solely because of their smallness) on the model of those which our senses perceive occurring in large bodies, than it is to devise I know not what new things, having no similarity with those things which are observed, in order to give an account of those things [in tiny bodies]. {E.g., prime matter, substantial forms, and all that great array of qualities which many are accustomed to assuming; each of which is more difficult to know than the things men claim to explain by their means} (IV, 201; 1982, 284).

In this passage Descartes does two things. On the one hand, he advances a *continuity thesis*: it is simpler and consonant with what our senses reveal to us to assume that the properties of micro-objects are the same as the properties of macro-objects. This continuity thesis is primarily methodological. It licenses certain kinds of explanations: those that endow matter in general, and hence the unobservable parts of matter, with the properties of the perceived bits of matter. It therefore licenses as explanatory certain kinds of unobservable configurations of matter; viz., those that resemble perceived configurations of matter. On the other hand, however, Descartes circumscribes mechanical explanation by noting *what it excludes*; that is by specifying what does not count as a proper scientific explanation. He's explicit that the Aristotelian-scholastic metaphysics of substantial forms and powerful qualities is precisely what is abandoned as explanatory by the mechanical philosophy[2].

All this was followed in the investigation of the mechanism of gravity and the (in)famous vortex hypothesis according to which the planets are carried by vortices around the sun. A vortex is a specific configuration of matter in motion—matter revolving around a centre. The underlying mechanism of the planetary system then is a system of vortices:

> [T]he matter of the heaven, in which the Planets are situated, unceasingly revolves, like a vortex having the Sun as its center, and […] those of its parts which are close to the Sun move more quickly than those further away; and […] all the Planets (among which we {shall from now on} include the Earth) always remain suspended among the same parts of this heavenly matter (III, 30; 1982, 196).

[2] In (IV, 204; 1982, 286) Descartes accepts that scientific explanation does not require the truth of the claims about the microconstituents of things. In the next paragraph, however, he argues that his explanations have 'moral certainty' (IV, 205; 1982, 286–7).

The very idea of this kind of configuration is suggested by experience, and by means of the bridge principle it is transferred to the subtle matter of the heavens. Hence, invisibility doesn't matter. The bridge principle transfers the explanatory mechanism from visible bodies to invisible bodies. More specifically, the specific continuity thesis used is the motion of "some straws {or other light bodies}… floating in the eddy of a river where the water doubles back on itself and forms a vortex as it swirls" (op.cit.). In this kind of motion we can see that the vortex carries the straws "along and makes them move in circles with it" (op.cit.). We also see that

> some of these straws rotate about their own centers, and that those which are closer to the center of the vortex which contains them complete their circle more rapidly than those which are further away from it (op.cit.).

More importantly for the explanation of gravity, we see that

> although these whirlpools always attempt a circular motion, they practically never describe perfect circles, but sometimes become too great in width or in length (op.cit.).

Given the continuity thesis, we can transfer this mechanical model to the motion of the planets and "imagine that all the same things happen to the Planets; and this is all we need to explain all their remaining phenomena" (op.cit.). Notably, the continuity thesis offers a heuristic for discovering plausible mechanical explanations.

Christiaan Huygens (1690) came to doubt the vortex theory "which formerly appeared very likely" to him (1997, 32). He didn't thereby abandon the key tenet of mechanical philosophy. For Huygens too the causal explanation of a natural phenomenon had to be mechanical. He said referring to Descartes:

> Mr Descartes has recognized, better than those that preceded him, that nothing will be ever understood in physics except what can be made to depend on principles that do not exceed the reach of our spirit, such as those that depend on bodies, deprived of qualities, and their motions (1997, 1–2).

Huygens posited a fluid matter that consists of very small parts in rapid motion in all directions and which fills the spherical space that includes all heavenly bodies. Since there is no empty space, this fluid matter is more easily moved in circular motion around the centre, but not all parts of it move in the same direction. As Huygens put it "it is not difficult now to explain how gravity is produced by this motion" (1997, 16). When the parts of the fluid matter encounter some bigger bodies, like the planets: "these bodies [the planets] will necessarily be pushed towards the center of motion, since they do not follow the rapid motion of the aforementioned matter" (op.cit.). And he added:

> This then is in all likelihood what the gravity of bodies truly consists of: we can say that this is the endeavor that causes the fluid matter, which turns circularly around the center of the Earth in all directions, to move away from the center and to push in its place bodies that do not follow this motion (op.cit).

In fact, Huygens devised an experiment with bits of beeswax to show how this movement towards the centre can take place.

Newton of course challenged all this, and along the line, the very idea that causal explanation should be *mechanical*. But before we take a look at his reasons and their importance for the very idea of scientific explanation, we should not fail to see the broader metaphysical grounding of the mechanical project. For, as we noted, in the seventeenth century Mechanism offered the metaphysical foundation of science.

2.2.2 Mechanical vs Non-mechanical Explanation

The contours of this endeavour are well-known. Matter and motion are the 'ultimate constituents' of nature; or, as Robert Boyle (1991, 20) put it, the "two grand and most catholic principles of bodies". Hence, all there is in nature (but clearly not the Cartesian minds) is determined (caused) by the mechanical affections of bodies and the mechanical laws. Here is Boyle again:

> [T]he universe being once framed by God, and the laws of motion being settled and all upheld by his incessant concourse and general providence, the phenomena of the world thus constituted are physically produced by the mechanical affections of the parts of matter, and what they operate upon one another according to mechanical laws (1991, 139).

The Boylean conception, pretty much like the Cartesian, took it that the new mechanical approach acquired content by excluding the then dominant account of explanation in terms of "real qualities": the scholastics "attribute to them a nature distinct from the modification of the matter they belong to, and in some cases separable from all matter whatsoever" (1991, 15–16). Explanation based on real qualities, which are distinct (and separable) from matter, is not a genuine explanation. They are posited without "searching into the nature of particular qualities and their effects" (1991, 16). They offer *sui generis* explanations: why does snow dazzle the eyes? Because of "a quality of whiteness that is in it, which makes all very white bodies produce the same effect" (1991, 16). But what is whiteness? No further story about its nature is offered, but just that it's a "real entity" inhering in the substance: why do white objects produce this effect rather than that? Because it is in their nature to act thus.

Descartes made this point too when, in his *Le Monde*, he challenged the scholastic rivals to explain how fire burns wood, if not by the incessant and rapid motion of its minute parts. In his characteristic upfrontness, Descartes contrasted two ways to explain how fire burns wood. The first is the Aristotelian way, according to which "the 'form' of fire, the 'quality' of heat, and the 'action' of burning" are "very different things in the wood" (Descartes 2004, 6). The other is his own mechanistic way: when the fire burns wood,

> it moves the small parts of the wood, separating them from one another, thereby transforming the finer parts into fire, air, and smoke, and leaving the larger parts as ashes (2004, 6).