European Studies in Philosophy of Science

Alexander Christian
David Hommen
Nina Retzlaff
Gerhard Schurz *Editors*

Philosophy of Science

Between the Natural Sciences, the Social Sciences, and the Humanities

Springer

European Studies in Philosophy of Science

Volume 9

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

Alexander Christian • David Hommen
Nina Retzlaff • Gerhard Schurz
Editors

Philosophy of Science

Between the Natural Sciences, the Social Sciences, and the Humanities

Springer

Editors
Alexander Christian
Düsseldorf Center for Logic and Philosophy of Science
Heinrich Heine University Düsseldorf
Düsseldorf, Germany

David Hommen
Düsseldorf Center for Logic and Philosophy of Science
Heinrich Heine University Düsseldorf
Düsseldorf, Germany

Nina Retzlaff
Düsseldorf Center for Logic and Philosophy of Science
Heinrich Heine University Düsseldorf
Düsseldorf, Germany

Gerhard Schurz
Düsseldorf Center for Logic and Philosophy of Science
Heinrich Heine University Düsseldorf
Düsseldorf, Germany

ISSN 2365-4228 ISSN 2365-4236 (electronic)
European Studies in Philosophy of Science
ISBN 978-3-319-72576-5 ISBN 978-3-319-72577-2 (eBook)
https://doi.org/10.1007/978-3-319-72577-2

Library of Congress Control Number: 2018931167

Printed on acid-free paper

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

Acknowledgment

The editors would like to thank Dennis Dieks, Maria Carla Galavotti, and Wenceslao J. Gonzalez for the inclusion of this volume in the European Studies in Philosophy of Science series.

We would like to thank our contributors for their competence, cooperativeness, and patience. Furthermore, we would like to express our gratitude to Paul Näger, Arne Weber, Ludger Jansen, Oliver Scholz, Andreas Hüttemann, Corina Strößner, Holger Lyre, Florian Boge, Alexander Gebharter, Christian Feldbacher-Escamilla, Georg Toepfer, Martin Carrier, and Susanne Hahn for reviewing the collected contributions.

Düsseldorf Center for Logic and Philosophy of Science
Heinrich Heine University Düsseldorf
Düsseldorf, Germany

Alexander Christian
David Hommen
Nina Retzlaff
Gerhard Schurz

Contents

Part I Philosophy of Physics

1 Are There Good Arguments Against Scientific Realism? 3
Paul Hoyningen-Huene

2 Quantum Gravity: A Dogma of Unification? 23
Kian Salimkhani

3 On Predictions and Explanations in Multiverse Scenarios 43
Keizo Matsubara

4 The Clock Paradox: Luise Lange's Discussion 55
Andrea Reichenberger

Part II Philosophy of Life Sciences

5 Bio-Agency and the Possibility of Artificial Agents 65
Anne Sophie Meincke

6 When Mechanisms Are Not Enough: The Origin of Eukaryotes and Scientific Explanation 95
Roger Deulofeu and Javier Suárez

7 Functions, Malfunctioning, and Negative Causation 117
Ludger Jansen

8 Disease Entities, Negative Causes, Multifactoriality, and the Naturalness of Disease Classifications. Remarks on Some Philosophical Misperceptions of Medical Pathology 137
Peter Hucklenbroich

Part III Philosophy of Social Sciences and Values in Science

9 Identifying Agnotological Ploys: How to Stay Clear of Unjustified Dissent 155
Martin Carrier

10 The "Ought"-Dimension in Value Theory: The Concept of the Desirable in John Dewey's Definition of Value and Its Significance for the Social Sciences 171
Elizaveta Kostrova

11 From Stability to Validity: How Standards Serve Epistemic Ends ... 187
Lara Huber

Part IV Philosophy of Mathematics and Formal Modeling

12 Constitutive Inference and the Problem of a Complete Variation of Factors 205
Jens Harbecke

13 A Partial Calculus for Dag Prawitz's Theory of Grounds and a Decidability Issue 223
Antonio Piccolomini d'Aragona

14 Models in Search of Targets: Exploratory Modelling and the Case of Turing Patterns 245
Axel Gelfert

Author Index 271

Subject Index 273

Contributors

Antonio Piccolomini d'Aragona is a PhD student at Aix-Marseille University and "La Sapienza" University of Rome and a lecturer in logic at the Department of Philosophy of Aix-Marseille University. He works on Dag Prawitz's recent theory of grounds, under the conjoint direction of Prof. Gabriella Crocco, Aix-Marseille University, and Prof. Cesare Cozzo, "La Sapienza" University of Rome; his research areas are broadly mathematical logic and philosophy of logic, with the main focus on proof-theoretic semantics, verificationist theories of meaning, inferentialism, and type theories.

Martin Carrier is professor of philosophy at Bielefeld University and director of the Institute for Interdisciplinary Studies of Science (I2SoS). He earned his PhD at the University of Münster, spent his postdoc period at the University of Konstanz, and became professor of philosophy at the University of Heidelberg. Since 1998, Carrier has worked in Bielefeld. His chief area of research is the philosophy of science, in particular historical changes in science and scientific method, theory-ladenness and empirical testability, and presently the relationship between science and values and science operating at the interface with society. In this latter field, he addresses methodological changes imposed on science by the pressure of practice. He is a member of various German and European Academies of Science. He was awarded the Leibniz Prize of the German Research Association (DFG) for 2008, the Blaise Pascal Medal in Social Sciences and Humanities by the European Academy of Sciences for 2015, and the John G. Diefenbaker Award by the Canada Council for the Arts for 2016.

Roger Deulofeu is a PhD student at Logos Research Group, University of Barcelona. He is working on the notion of scientific laws and explanation in science, with a particular emphasis on the biological domain, arguing that explanation in biology does not uniquely work by describing mechanisms but by identifying regularities that make biological phenomena expectable.

Axel Gelfert received his PhD in History and Philosophy of Science from the University of Cambridge. He has held fellowships and appointments in Budapest, Edinburgh, and Singapore, and is currently Professor of Philosophy at the Technical University of Berlin. He is the author of *A Critical Introduction to Testimony* (Bloomsbury 2014) and *How to Do Science With Models: A Philosophical Primer* (Springer 2016).

Jens Harbecke is a professor of theoretical philosophy and philosophy of social sciences at Witten/Herdecke University, Germany. He is also the project coordinator of a European research project (www.insosci.eu) on the philosophy of social science and neuroscience, and he collaborates as a principal investigator within a philosophical research project funded by the German-Israeli Foundation (www.philosophy-cognitive-science.com/) on causation and computation in neuroscience. His research focuses on constitutive explanations in economics and neurosciences. He also works on questions about causality in the metaphysics of mind and on counterfactual and regularity theories of causation. His recent publications include "The regularity theory of mechanistic constitution and a methodology for constitutive inference," published in *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* (2015); "Regularity constitution and the location of mechanistic levels," published in *Foundations of Science* (2015); and "The role of supervenience and constitution in neuroscientific research," published in *Synthese* (2014).

Paul Hoyningen-Huene is a philosopher of science with a PhD in theoretical physics. In 2014, he retired from his professorship for theoretical philosophy, especially philosophy of science, at the Institute of Philosophy of Leibniz University of Hannover, Germany. He teaches now philosophy of economics at the Department of Economics of the University of Zurich, Switzerland. He is best known for his books *Reconstructing Scientific Revolutions: Thomas S. Kuhn's Philosophy of Science* (1993), *Formal Logic: A Philosophical Approach* (2004), and *Systematicity: The Nature of Science* (2013).

Lara Huber lectures in research ethics and philosophy of science at Kiel University. Her current research focuses on norms in the sciences from the perspective of epistemology and action theory. She has published on modelling and further topics in the philosophy of the life sciences (e.g., *Philosophie der biomedizinischen Wissenschaften*, in: Grundriss Wissenschaftsphilosophie, Die Philosophien der Einzelwissenschaften, ed. by Simon Lohse and Thomas Reydon, pp. 287–318, with Lara K. Keuck, Hamburg: Meiner Verlag 2017). She is the co-editor of *Standardization in Measurement: Philosophical, Historical and Sociological Issues* with Oliver Schlaudt (London: Routledge / Pickering & Chatto 2015), and recently has completed a monograph on scientific concepts and societal perceptions of normality: *Normal* (Hamburg: Textem, forthcoming).

Peter Hucklenbroich Dr. med., Dr. phil., is professor of philosophy and history of medicine at the Medical Faculty and University Hospital in Münster, F.R.G. From 1995 to 2015, he has been director of the Institute of Ethics, History, and Theory of Medicine in Münster. He has been chairman and cochairman of the Center for Philosophy of Science, the Clinical Ethics Committee, and the Institutional Review Board at the University of Münster. He has published numerous books and papers about philosophy of natural science, philosophy of medicine, and the medical concept of disease. His most recognized scientific contributions are the book *Wissenschaftstheoretische Aspekte des Krankheitsbegriffs* (*Philosophical Aspects of the Concept of Disease*, Münster 2013) and the paper "'Disease entity' as the key theoretical concept of medicine" (Journ Med Phil 39, 2014).

Ludger Jansen teaches philosophy at the Ruhr University Bochum and the University of Rostock. He has a strong research interest in the metaphysics of science, including topics like dispositions, functions, and causation. Together with Barry Smith, he has published the first introduction to applied ontology in German.

Elizaveta Kostrova is a research fellow at Sociology of Religion Research Seminar at St Tikhon's Orthodox University, Moscow. Her research focuses on philosophical interpretations of the Other and intersubjectivity, as well as their possible connections to social sciences and religion. She is interested in how social interaction (especially "unselfish" and "disinterested" kind of it) can be conceptualized and grounded philosophically.

Keizo Matsubara has received two PhD degrees from Uppsala University, one in theoretical physics (2004) and one in theoretical philosophy (2013). He is currently a postdoc working at the University of Illinois at Chicago within the project *Space and Time After Quantum Gravity.*

Anne Sophie Meincke is a research fellow at the Centre for the Study of Life Sciences (Egenis) at the University of Exeter. She works at the intersection of metaphysics and the philosophy of biology, focusing in particular on the implications of a process ontological concept of the organism for identity (biological and personal), agency, and free will. Meincke's master's and PhD studies were funded by the German Academic Scholarship Foundation. In 2014, Meincke was awarded the annual Prize for Scientific Research of the City of Innsbruck. She also won, together with John Dupré, the 2015/2016 annual conference grant of the Institute of Philosophy, UCL London, which led to an interdisciplinary conference on "Biological Identity" in summer 2016. Meincke's recent and forthcoming publications include *Auf dem Kampfplatz der Metaphysik: Kritische Studien zur transtemporalen Identität von Personen* (*On the Battlefield of Metaphysics: Critical Studies on the Transtemporal Identity of Persons*) (2015); "Potentialität und Disposition in der Diskussion über den Status des menschlichen Embryos: Zur Ontologie des Potentialitätsarguments" ("Potentiality and disposition in the debate on the status of the human embryo: On the ontology of the argument from potentiality") (2015); *Dispositionalism: Perspectives from Metaphysics and the Philosophy of Science* (as editor) (forthcoming); "How to stay the same while changing: Personal identity as a test case for reconciling 'analytic' and 'continental' philosophy through process ontology," in *Analytic-Bridge-Continental + (ABC+) Process Philosophy*, edited by R. Booth and Berlin et al. (forthcoming); and "Persons as Biological Processes. A Bio-Processual Way-Out of the Personal Identity Dilemma," in *Everything Flows: Towards a Process Philosophy of Biology*, edited by D. Nicholson and J. Dupré (forthcoming).

Andrea Reichenberger is currently working as research assistant at the Center for History of Women Philosophers and Scientists, Faculty of Arts and Humanities, Department of Philosophy, Paderborn University. Her research interests focus on the history and philosophy of physics, especially on women's studies. Awards include Certificate Colloquium Logicum 2006, DVMLG, and Certifico Institutio de Física de Líquidos y Systemas Biológicos La Plata 2010. Recent publications include *Émilie Du Châtelet's Institutions physiques: Über die Rolle von Prinzipien und Hypothesen in der Physik* (Springer 2016).

Kian Salimkhani is a PhD student and research associate at the Institute for Philosophy at the University of Bonn and a member of the DFG-funded research unit Inductive Metaphysics. His research interests include philosophy of physics (especially spacetime theories and quantum field theory), general philosophy of science, and metaphysics. In his PhD project, he investigates the issue of fundamentality of spacetime. He studied theoretical physics and philosophy in Bonn.

Javier Suárez is a PhD student at Egenis, the Centre for the Study of Life Sciences, University of Exeter. He is working on the intersection between philosophy of science and philosophy of biology with particular emphasis on the implications of symbiosis research for evolutionary theory, as well as for traditional topics in philosophy of science (scientific explanation, scientific representation, and the use of model organisms in science).

Introduction

This volume contains a selection of papers delivered at the Second International Conference of the German Society for Philosophy of Science (Gesellschaft für Wissenschaftsphilosophie, GWP) which took place at the Heinrich Heine University in Düsseldorf, Germany, from March 8 to 11, 2016, and was hosted by the Düsseldorf Center for Logic and Philosophy of Science (DCLPS). GWP.2016 was sponsored by the Heinrich Heine University Düsseldorf and the Düsseldorf Center for Logic and Philosophy of Science, the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG), and the *Journal for General Philosophy of Science* (Springer). The GWP organizers were Holger Lyre (Magdeburg), Ulrich Krohs (Münster), Thomas Reydon (Hanover), and Uljana Feest (Hanover). The Local Organization Committee consisted of Gerhard Schurz (chair), Alexander Christian, Christian J. Feldbacher-Escamilla, Alexander Gebharter, David Hommen, Nina Retzlaff, and Paul Thorn.

The aim of GWP.2016 was to enable philosophers of science from Germany and other countries to meet and engage in fruitful discussions on current research topics in philosophy of science and to strengthen the international philosophy of science community. It was also intended to bring together philosophers of science working in different fields of philosophy of science; accordingly, the organizers decided to entitle GWP.2016 "Philosophy of Science: Between the Natural Sciences, the Social Sciences, and the Humanities." Since GWP.2016 comprised a number of outstanding contributions, the organizers decided to publish this volume, which is included in the Springer book series of the European Philosophy of Science Association, besides a special issue of the *Journal for General Philosophy of Science* (JGPS) devoted to GWP.2016.

GWP.2016 had more than 150 participants (approx. one-third were women and about one-fifth were students or graduate students), who came from 16 European and 6 non-European countries. There were 6 plenary lectures given by invited speakers, 62 contributed papers, and 7 contributed symposia (with 19 symposia talks). All in all, GWP.2016 featured 87 talks. The plenary lectures were given by Rainer Hegselmann (Bayreuth), Paul Hoyningen-Huene (Hanover), Michela Massimi (Edinburgh), Stathis Psillos (Athens), Alexander Rosenberg (Duke), and

Gila Sher (San Diego). The conference featured contributed papers and symposia covering all subfields of philosophy of science. The main sections were general philosophy of science (approx. 30%), philosophy of life sciences (approx. 20%), philosophy of natural sciences (approx. 15%), and philosophy of social sciences and humanities (approx. 10%). There were also sections on other fields of philosophy of science and also on more specific topics (all in all approx. 25%). In particular, these were causality, confirmation, history of philosophy of science, mechanisms, philosophy of mathematics, and values in science. The seven symposia dealt with absences in biological and medical explanations, constitution, genetics and culture, philosophy of science and engineering, and quantum gravity.[1]

The list of authors who agreed to contribute to this collection includes renowned experts from several fields in philosophy of science who contributed talks to GWP.2016, including one invited talk of GWP.2016, for which we are particularly thankful. Moreover, the collection presents research of young scientists and has a comparably high share of female authors (one-third).

The essays in this volume are divided into four parts: (1) philosophy of physics, (2) philosophy of life sciences, (3) philosophy of social sciences and values in science, and (4) philosophy of mathematics and formal modeling. We hope that the collection provide insights into a number of ongoing discussions in important subfields of philosophy of science and it will therefore be interesting for an interdisciplinary and multidisciplinary readership.

Philosophy of physics: This part includes papers on unification in high energy physics, cosmology, and causation in physics, including contributions about core arguments in favor of scientific realism, the unification of fundamental forces in physics, testability of multiverse theories, and causal determination in spacetime theories.

In his contribution, **Paul Hoyningen-Huene** addresses two famous arguments in favor of scientific realism. He first discusses a peculiarity of the realism-antirealism debate. Some authors defending antirealist positions in a philosophical discussion seem to be inconsistent with what they do when treating scientific subjects. In the latter situation, they behave as realists. Hoyningen-Huene argues that this tension can be dissolved by distinguishing different discourses belonging to different levels of philosophical radicality. Depending on the respective level, certain presuppositions are either granted or questioned. The author then turns to a discussion of the miracle argument by discussing a simple example of curve fitting. In the example, multiple use-novel predictions are possible without indicating the truth of the fitting curve. It is argued that because this situation has similarities with real scientific cases, it sheds serious doubt upon the miracle argument. Next, Hoyningen-Huene discusses the strategy of selective realism, especially its

[1]For more information about GWP.2016, please see Christian, A., Feldbacher-Escamilla, C. J., and Gebharter, A. (2016). The Second International Conference of the German Society for Philosophy of Science (GWP.2016), March 8–11, 2016. *Journal for General Philosophy of Science*, 1–3. http://doi.org/10.1007/s10838-016-9358-4.

additional crucial component, the continuity argument. The continuity of some X in a series of theories, with X being responsible for the theories' use-novel predictions, is taken to be a reliable indicator for the reality of X. However, the continuity of X could as well be due to the similarity of the theories in the series with an empirically very successful theory embodying X, without X being real. Thus, the author concludes that the two main arguments for scientific realism show severe weaknesses.

Kian Salimkhani's contribution deals with the central challenge of fundamental physics to develop a unified theory of quantum gravity (QG): the combination of general relativity and quantum mechanics. The common conviction is that the quest for QG is not only fueled but generated by *external* principles and hence driven, first and foremost, by reasoning involving philosophical assumptions. Against this, Salimkhani claims that it is exactly the particle physics stance – taken, e.g., by Weinberg and others – that reveals the issue of QG as a genuine physical problem arising within the framework of quantum field theory (QFT). Salimkhani argues that the quest for QG sets an important and often misconceived example of physics' *internal* unificatory practice. Physics' internal strategies – e.g., exploiting the explanatory capacities of an established theory – suffice to explain the search for a theory of quantum gravity. To set the stage for his argument, the author recaps what the research program of QG is about and what remarks suspecting a "dogma of unification" amount to. Subsequently, two important consequences for our understanding of general relativity (GR) and the issue of QG are briefly discussed: First, it is suggested that we should not take GR as a fundamental theory because it can be reduced to QFT. Second, the investigation serves as a clarification of what the problem with QG actually is. Afterward, some objections against the advocated picture are mentioned and very briefly replied to, before the author revisits the opening question concerning the alleged "dogma of unification."

Keizo Matsubara discusses predictions and explanations in multiverse scenarios. Many researchers in contemporary physics take the possibility that our universe is just one of many in a multiverse seriously. In the current debate, however, speculations about multiverses are often connected to arguments using the controversial anthropic principle, which many critics find to be untestable and unscientific. In his contribution, Matsubara suggests criteria that need to be satisfied before a multiverse theory should be considered scientifically respectable. While presently proposed multiverse scenarios do not yet live up to criteria strong enough to be counted as part of well-established science, the author argues that one could in principle find good scientific reasons for accepting a theory entailing that we live in a multiverse. Multiverse theories, if sufficiently developed, can have testable predictions. Accordingly, Matsubara is interested in the question how we in principle can test *specific* multiverse theories, as opposed to evaluating the generic idea that we live in a multiverse. For this, Matsubara focuses on string theory and its multiple stable solutions, which for Matsubara represent a landscape of possible multiverses. In some cases, a multiverse theory can be testable; however, to properly test a multiverse theory, it is important to distinguish new predictions from explanations based on the multiverse.

Andrea Reichenberger devotes her contribution to the work of mathematician and physician Luise Lange (1891–1978). In her articles on the clock paradox and the relativity of time, Lange defends the theory of relativity against philosophical refutations. The clock paradox concerns the phenomenon of time dilation, which is a direct consequence of special relativity: if there are two synchronous clocks at the same inertial reference frame and one of them is moved along a closed curve with constant velocity until it has returned after some time to its point of departure, this clock will lag on its arrival behind the clock that has not been moved. This effect seems to be paradoxical because, in relativity, it appears that either clock could "regard" the other as the traveler, in which case each should find the other delayed – a logical contradiction. Lange shows, however, that the apparent clock paradox is not a paradox but merely conflicts with common sense and is based on a misunderstanding of the theory. Reichenberger's study explores, contextualizes, and analyzes Lange's clear and sophisticated contribution to the debate for the first time.

Philosophy of life sciences: This part begins with a contribution by **Anne Sophie Meincke** about recent developments in the philosophy of biology toward a biologically grounded concept of agency. Herein, agency is described as bio-agency: the intrinsically normative adaptive behavior of human and nonhuman organisms, arising from their biological autonomy. Meincke's contribution assesses the bio-agency approach by examining criticism recently directed by its proponents against the project of embodied robotics. Defenders of the bio-agency approach have claimed that embodied robots do not, and for fundamental reasons cannot, qualify as artificial agents because they do not fully realize biological autonomy. More particularly, it has been claimed that embodied robots fail to be agents because agency essentially requires metabolism. Meincke argues that this criticism, while being valuable in bringing to the fore important differences between bio-agents and existing embodied robots, nevertheless is too strong. It relies on inferences from agency-as-we-know-it to agency-as-it-could-be which are justified neither empirically nor conceptually.

Roger Deulofeu and **Javier Suárez** focus on their contribution on the common appeal to mechanistic explanations in contemporary philosophy of science. Mechanists argue that an explanation of a phenomenon consists of citing the mechanism that brings the phenomenon about. In their contribution, the authors present an argument that challenges the universality of mechanistic explanation: in explanations of the contemporary features of the eukaryotic cell, biologists appeal to its symbiogenetic origin. Therefore, the notion of symbiogenesis plays the main explanatory role. Deulofeu and Suárez defend the notion that symbiogenesis is non-mechanistic in nature and that any attempt to explain some of the contemporary features of the eukaryotic cell mechanistically turns out to be at least insufficient and sometimes fails to address the question that is asked. Finally, the authors suggest that symbiogenesis is better understood as a pragmatic scientific law and present an alternative non-mechanistic model of scientific explanation. In the model they present, the use of scientific laws is supposed to be a minimal requirement of all scientific explanations, since the purpose of a scientific explanation is to make phenomena expectable. Therefore, this model would help to understand biologists' appeal to the notion of symbiosis and thus is shown to be better, for the case under examination, than the mechanistic alternative.

Ludger Jansen's contribution is concerned with functional explanations, which interestingly apply not only in cases of normal functioning but also in the case of malfunctioning. According to a straightforward analysis, a bearer of the function to F is malfunctioning if and only if it does not F although it should do so. This makes malfunctions and malfunctionings analogous to negative causation and thus problematic, because they seem to involve absent dispositions and absent processes. This analysis seems also to require that the function to F cannot be identical with the disposition to F. Thus, we seem to be trapped in a dilemma: If the realm of functions is separated from the realm of dispositions, then it seems that functions cannot be causally efficacious. Alternatively, functions are considered to be identical with dispositions, but then malfunctioning seems to be conceptually impossible. Jansen's contribution defends and further develops the thesis of Röhl and Jansen that functions are not a special type of dispositions. For this purpose, it first reviews different varieties of malfunction and malfunctioning and suggests definitions of both malfunction and malfunctioning. The author discusses the special-disposition account of the basic formal ontology (BFO), which Spear et al. have defended by suggesting various strategies on how a special-disposition account can deal with malfunctions. On the one hand, Jansen's contribution evaluates these strategies and indicates several problems arising from them. On the other hand, it describes how to account for the non-optionality and the causal efficacy of functions, if functions are not dispositions. While function types are not identical to disposition types, there are important interrelations between functions and dispositions, namely, (1) heuristically, (2) from a design perspective for artifact functions, and (3) from an evolutionary perspective for types of biological functions.

Peter Hucklenbroich's contribution deals with disease entities and the naturalness of disease classifications in medical pathology. In the twentieth- and twenty-first-century medicine, the concept of a disease entity has proven to be of key importance for pathology and the theory of diseases. Disease entities are kinds of complex clinical and etiopathogenetic processes that are triggered by specific primary causes and develop on anatomical, physiological, clinical, and subjectively experienced levels. They are distinguished from healthy states of life by definite criteria of pathologicity. Hucklenbroich sketches the prehistory as well as the central features of the current paradigm of disease entities. Since the 1970s, philosophical theories of disease tend to ignore or, at best, reject this concept. By examining the well-respected theories of H. Tristram Engelhardt, Jr., and Caroline Whitbeck, it is shown that this defensive attitude results from a philosophical misconception of the concept. Engelhardt criticizes the concept of disease entity because he erroneously assumes, as Hucklenbroich argues, that explanations using this concept are inconsistent with explanations by laws of physiology. On the other hand, Whitbeck correctly refers to the modern, scientific version of the concept. But in her opinion, the concept "cause of disease" is defined according to certain "instrumental interests" that may differ between subjects and is, thus, neither objective nor unique and unequivocal. Hence, the concept of disease entity is ambiguous and not suited for establishing a unique, unambiguous, and unequivocal *natural classification* of diseases. Hucklenbroich shows that Whitbeck's objections rest upon misconceptions concerning the concept of "primary cause," i.e., "etiological factor," and of the so-called "multi-factorial" causation. By reference to a careful, medically and philosophically correct reconstruction of these concepts, he aims to show that her objections do not apply.

Philosophy of social sciences and values in science: This part starts with a contribution by **Martin Carrier** who addresses matters of agnotology, a research field decisively influenced by Robert Proctor, who introduced the notion in 1992. Agnotology refers to the active creation and preservation of confusion and ignorance. Focusing on his contribution to the intentional production of misleading information or the deliberate creation of epistemically detrimental dissent, however, Carrier recognizes several nontrivial epistemological problems requiring clarification. First, the purpose of generating confusion is typically difficult to ascertain. Accordingly, identifying a publicly accessible mistake would be helpful for pinpointing agnotological ploys. Second, the idea underlying Proctor's notion is that sociopolitical motives have trumped or outplayed the quest for knowledge. However, implementing this idea demands the distinction between epistemic and non-epistemic values. The former appreciate knowledge and understanding, while the latter refer to sociopolitical interests and utility. Many philosophers of science do not acknowledge an in-principle distinction between the two. At the same time, they are committed to scientific pluralism. Both considerations come together in raising the problem which methodological standards are violated in the production and maintenance of ignorance. Carrier proposes to identify agnotological ploys by the discrepancy between the conclusions suggested by the design of a study and the conclusions actually drawn or indicated. This mechanism of "false advertising" serves to implement agnotological ploys and helps to identify them without having to invoke the intentions of the relevant agents. The author discusses three agnotological cases, i.e., studies on bisphenol A, Bt-maize/Roundup, and Gardermoen's airport in Oslo. Pinpointing agnotological endeavors is a means for weeding out approaches that look fitting at first glance but which are, in fact, blatantly inappropriate. Identifying such endeavors serves to reduce the range of studies under consideration and thus helps to manage pluralist diversity.

Elizaveta Kostrova investigates in her contribution the "ought" dimension in value theory and John Dewey's notion of the desirable from a philosophical as well as a sociological standpoint. The concept of "value" is widely used in various fields, and it has recently become the subject of empirical research. However, there is no common understanding of what it is. From the very start, the scope of value has been part of the opposition of what "is" to what "ought to be," and the fact that value judgments contained a normative element seemed to make the exclusion of value from the area of scientific analysis inevitable. As Kostrova shows in her contribution, John Dewey offers a different way of reasoning about values, which would allow scientists to keep the normativity in a way of saving the specificity of the concept. In order to do this, Dewey links the source of value with the evaluation process and introduces the concept of the "desirable" drawing the line between the "desirable" and the "desired." Clyde Kluckhohn later borrowed this concept from Dewey while formulating the concept of values within Parsons' theory of action. Thanks to him, the "desirable" has become a favorite part of value definition among different researchers. As a result of this development, the concept of "desirability" has been transformed: for example, in social psychology, the "desirable" has moved closer to the "important," and the significance of the normative aspect has diminished, evolving to a more descriptive understanding, while the social dimension, though present already in Dewey, has greatly increased. Kostrova's contribution considers the appearance of Dewey's notion of the desirable in the definition of value as well as its role in it and its further application in the study of values.

Lara Huber analyzes how standards shape scientific knowledge. Standards are said to provide trust in scientific methodology in general and measuring devices in particular. To standardize means to formalize and regulate scientific practices and to prioritize instrumental and methodological prerequisites of research: Standardization impacts on the design of experiments concern the reporting of outcomes and the assessment of research (e.g., peer review process). Studies in the history of science and technology have shown that standards contribute significantly to the evolution and validation of scientific practices. The philosophy of science is as yet only beginning to analyze systematic challenges posed by standardization. The main interest of Huber's contribution is to elaborate on the question how standards relate to ends that facilitate and/or allow for knowledge claims in experimental sciences in general. The author intends to inform about scientific practices in different fields of research that address given ends of standardization. First of all, Huber presents three examples of standards in science. Her contribution then focuses on three ends purported to serve epistemic needs in different fields of scientific inquiry: stability, homogeneity, and internal validity. She presents three case studies on standardization in different fields of scientific research, ranging from physics and measurement science to population-based trial design in psychology and medicine, in order to inquire into the reality of standards as being very specific tools with defined uses while sharing general suppositions about which ends they serve within the realm of science.

Philosophy of mathematics and formal modeling: This part starts with a contribution by **Jens Harbecke** who addresses a potential problem for his offered methodology of constitutive inference in the context of mechanistic explanation. According to the mechanistic approach, an adequate explanation demands an analysis of the mechanisms "underlying" an explanandum phenomenon at several levels. A central challenge for this approach consists in offering an account of how such mechanistic explanations can be established. As many authors have observed, the relationship between phenomena and their mechanisms cannot be a causal one, because a causal relationship is commonly considered to hold only between non-overlapping events, but a mechanism is believed to overlap with the phenomenon in space and time. Their noncausal and synchronous relation is usually referred to as "constitution." The problem seems to be that even when all causal relationships among mechanisms or parts of mechanism have been identified, it remains unclear whether all constitutive relationships among mechanisms and phenomena have been established thereby as well. Against this, Harbecke argues that it is possible to explicate a methodology for the establishment of constitutive explanations, although the latter differs substantially from methodologies establishing causal relationships. Harbecke's so-called methodology of constitutive inference is ultimately based on Mill's "method of difference," which requires a complete variation of factors in a given frame. In constitutive contexts, however, such a complete variation is often impossible. The author offers a solution to this problem that utilizes the notion of a "mechanism slice." In a first step, an example of a currently accepted explanation in neuroscience is reconstructed, which serves as a reference point of the subsequent discussion. It is argued that the proposed solution accommodates well all schematic situations in which the impossibility of varying all test factors could be expected either to lead to false inferences or to preclude the establishment of correct constitutive claims.

Antonio Piccolomini d'Aragona considers Dag Prawitz's recent theory of grounds. Since the 1970s, Prawitz has been interested in general proof theory. His normalization theorems play in natural deduction systems the role that Gentzen's cut-elimination plays in sequent calculi, a syntactic result which is extended to semantics through what Schroeder-Heister calls the "fundamental corollary of normalization theory," stating that every closed derivation in intuitionistic logic can be reduced to one using an introduction rule in its last step. The framework is inspired by Gentzen's notion that the introduction rules represent the definitions of the symbols concerned, and the elimination rules are no more than the consequences of these definitions. According to Prawitz, however, this is not the only possible approach to general proof theory, since one could also try to give a direct characterization of different kinds of proofs. From this standpoint, the influence of Gentzen and Dummett is accompanied by references to the Brouwer-Heyting-Kolmogorov (BHK) clauses. Already in 1977, Prawitz addressed the non-decidable character of the BHK proofs. In his more recent papers, Prawitz provides indications on how the ground-theoretic framework should be developed. However, the overall project still seems to be in an embryonic stage. In his contribution, Piccolomini d'Aragona addresses a threefold task. First, he analyzes the decidability problem within the BHK approach. Next, the author proposes a partial calculus for Prawitz's theory of grounds. After introducing a core calculus for Gentzen's introductions, he defines two expansions of it, one for full first-order minimal logic and another for a kind of "metalanguage" of grounds. These expansions help understand the final task, a ground-theoretic reformulation of the BHK decidability issue.

The final contribution by **Axel Gelfert** analyzes the concept and relevance of exploration in the context of scientific modeling. Traditional frameworks for evaluating scientific models have tended to downplay their exploratory function; instead they emphasize how models are inherently intended for specific phenomena and are to be judged by their ability to predict, reproduce, or explain empirical observations. By contrast, Gelfert argues that exploration should stand alongside explanation, prediction, and representation as a core function of scientific models.

Thus, models often serve as starting points for future inquiry, as proofs of principle, as sources of potential explanations, and as a tool for reassessing the suitability of the target system (and sometimes of whole research agendas). This is illustrated by a case study of the varied career of reaction-diffusion models in the study of biological pattern formation, which was initiated by Alan Turing in a classic 1952 paper. Initially regarded as mathematically elegant, but biologically irrelevant, demonstrations of how, in principle, spontaneous pattern formation could occur in an organism, such Turing models have only recently rebounded, thanks to advances in experimental techniques and computational methods. The long-delayed vindication of Turing's initial model, the author argues, is best explained by recognizing it as an exploratory tool (rather than as a purported representation of an actual target system).

Düsseldorf Center for Logic and Philosophy of Science
Heinrich Heine University Düsseldorf
Düsseldorf, Germany

Alexander Christian
David Hommen
Nina Retzlaff
Gerhard Schurz

Part I
Philosophy of Physics

Chapter 1
Are There Good Arguments Against Scientific Realism?

Paul Hoyningen-Huene

Abstract I will first discuss a peculiarity of the realism-antirealism debate. Some authors defending antirealist positions in a philosophical discussion seem to be inconsistent with what they do when treating scientific subjects. In the latter situation, they behave as realists. This tension can be dissolved by distinguishing different discourses belonging to different levels of philosophical radicality. Depending on the respective level, certain presuppositions are either granted or questioned. I will then turn to a discussion of the miracle argument by discussing a simple example of curve fitting. In the example, multiple use-novel predictions are possible without indicating the truth of the fitting curve. Because this situation has similarities with real scientific cases, it sheds serious doubt upon the miracle argument. Next, I discuss the strategy of selective realism, especially its additional crucial component, the continuity argument. The continuity of some X in a series of theories, with X being responsible for the theories' use-novel predictions, is taken to be a reliable indicator for the reality of X. However, the continuity of X could as well be due to the similarity of the theories in the series with an empirically very successful theory embodying X, without X being real. Thus, the two main arguments for scientific realism show severe weaknesses.

Keywords Miracle argument · Use-novel predictions · Continuity argument · Selective realism · Structural realism

P. Hoyningen-Huene (✉)
Institute of Philosophy, Leibniz University of Hanover, Hanover, Germany

Department of Economics, University of Zurich, Zurich, Switzerland
e-mail: hoyningen@ww.uni-hannover.de

A. Christian et al. (eds.), *Philosophy of Science*, European Studies in Philosophy of Science 9, https://doi.org/10.1007/978-3-319-72577-2_1

1.1 Introduction

There is a plausible *prima facie* answer to the title question whether there are good arguments against scientific realism, which simply is no! The source for this answer is the ubiquitous behavior of scientists, more specifically of physicists: they are usually straightforward realists when it comes to discussing scientific results. Good physicists have a solid education, are usually diligent, rational, intelligent, and self-critical people (at least as long as they talk science, not necessarily when they talk *about* science). Here is an example from recent, very topical science (suspect of earning some of its authors a Nobel Prize in physics). The upper half of Fig. 1.1 represents data that were measured on September 14, 2015 and published on Feb 11, 2016 (Abbott et al. 2016). The interpretation of these data is summarized in the conclusion of the paper:

> VIII. CONCLUSION
>
> The LIGO detectors have observed gravitational waves from the merger of two stellar-mass black holes. The detected waveform matches the predictions of general relativity for the inspiral and merger of a pair of black holes and the ringdown of the resulting single black hole. These observations demonstrate the existence of binary stellar-mass black hole systems. This is the first direct detection of gravitational waves and the first observation of a binary black hole merger.

The language of this conclusion (and of the whole body of the paper) is uncompromisingly realist: they "have observed gravitational waves", "the existence of binary stellar-mass black hole systems" is demonstrated, gravitational waves have been "directly" detected, and "a binary black hole merger" has been observed for the first time. There is no talk of or any argument for the given *realist* interpretation of the data: no other possibility is mentioned, let alone explicitly discarded based on some argument. Therefore, for the physicists involved – more than 1000 figure as authors

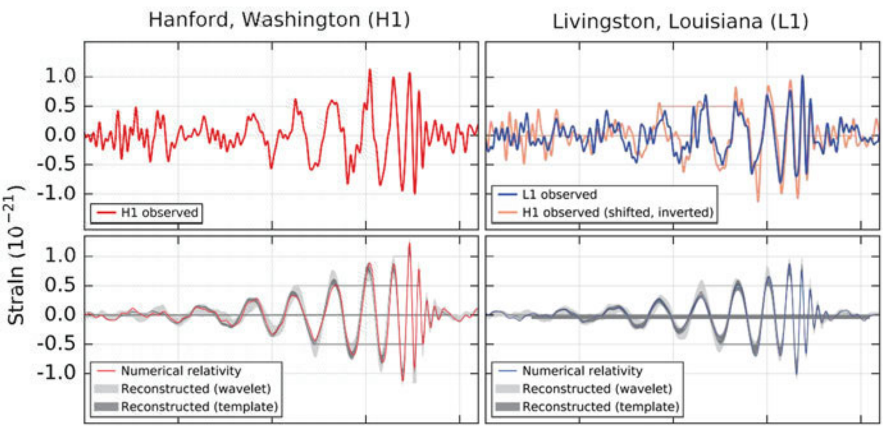

Fig. 1.1 Data for gravitational waves

of the paper – the case seems clear: they just detected really existing gravitational waves and observed the really existing merger of a pair of really existing black holes. Any argument for the evidently realist interpretation of the data is lacking. This suggests that the authors deem such an argument just totally unnecessary. If we stick to the hypothesis that this group of physicists is a bunch of fairly rational people, we must conclude that there simply are no serious arguments against the realist stance taken up in the paper, otherwise these arguments would have been confronted (and possibly disproved). Therefore, in the view of physics, as implicitly contained in the cited paper, the case seems clear: there are no serious arguments against scientific realism.

However, there seem to be serious dissenting voices: there are quite a few statements by (theoretical) physicists and chemists exactly to the contrary. A prominent example is Stephen Hawking:

> I take the positivist viewpoint that a physical theory is just a mathematical model and that it is meaningless to ask whether it corresponds to reality. All that one can ask is that its predictions should be in agreement with observation.[1]

This statement seems to be in blatant contradiction with the realist stance of the physicists who discovered gravitational waves. Is Hawking perhaps fundamentally different from these physicists? It may come as a surprise that he is not, at least as far as black hole physics and gravitational waves are concerned. In the context of the 1960s and 1970s discussion about the possible detection of gravitational waves, Hawking published a paper entitled "Gravitational radiation from colliding black holes" (Hawking 1971). Its abstract reads:

> It is shown that there is an upper bound to the energy of the gravitational radiation emitted when one collapsed object captures another. In the case of two objects with equal masses m and zero intrinsic angular momenta, this upper bound is $(2-\sqrt{2})\, m$.

Hawking refers to "gravitational radiation emitted" and "collapsed object[s]" (i.e., black holes), and there is no sign in the paper that these things are only calculational devices with no reality content, as one would expect from an instrumentalist. Instead, he speaks about them in the same language as one speaks about any ordinary real physical object. Hawking's stance in this paper is thus purely realist. However, what shall we make of this apparent contradiction between a purely realist and a radically instrumentalist stance occurring in the same author?

[1] Hawking (1996, 3–4). See also the very clear statement of the consequence of his positivism later in the book: "[Penrose] is worried that Schrödinger's cat is in a quantum state, where it is half alive and half dead. He feels that can't correspond to reality. But that doesn't bother me. I don't demand that a theory correspond to reality because I don't know what it is. Reality is not a quality you can test with a litmus paper. All I'm concerned with is that the theory should predict the results of measurements" (Hawking and Penrose 1996, 121). See also Hawking and Mlodinow (2010, esp. Chapter 3).

1.2 Levels of Philosophical Radicality

My suggestion is that we should distinguish, in somewhat fashionable terminology, different discourses, or: ways of reasonably discussing things (or "language games"). I shall describe the differences between these discourses as differences in the levels of their *philosophical radicality*. There is a ground level, or level zero, of philosophical radicality in which nothing is put into question for *philosophical* motives. On this level, nothing is doubted beyond what is doubted in normal scientific practice (or in everyday discourse, for that matter). For instance, in cutting edge scientific discourse about new hypothetical objects, many things are taken for granted, for instance realistically interpreted established theories and those parts of the experimental equipment that have been exhaustively tested. "Taken for granted" only means that these things are not questioned *in the given context* which does not, of course, exclude their being questioned in other contexts, be it scientific or philosophical contexts (more on the latter see below). For instance, in the recent discovery of gravitational waves and of inspiraling black holes, it was taken for granted (among many other things) that the theory on which the design of the lasers was based was correct, that the data that the two detectors produced were the result of optical interference, and that General Relativity Theory was the right theory to interpret the data (see Abbott et al. 2016).[2] The question in focus was the existence of gravitational waves and, for any particular case, their concrete sources. Clearly, this is a thoroughly realist stance: the pertinent scientific theories are interpreted realistically, and the question is whether gravitational waves really exist and what their sources are. Thus, the enterprise is a purely scientific one, devoid of any *additional* philosophical questioning.

In the given context, the first level of philosophical radicality is reached by questioning *in general* the step to a realist interpretation of scientific theories. This is what the standard philosophy of science discussion about scientific realism is all about. In this case, our knowledge of observable macroscopic objects as real objects is typically taken for granted. The question being asked is this: Are we in general justified to assume the existence and properties of those unobservable

[2]A referee of an earlier version of this paper objected to my description of level zero of philosophical radicality that "it is entirely legitimate for a scientist to question background theories in order to draw into doubt a conclusion like the detection of gravitational waves. Double checking and questioning scientific background assumptions fully plays out at the scientific level and constitutes an important element of scientific reasoning." No and yes. For instance, doubting the putative detection of gravitational waves on the basis that the use of Maxwell's equations should be questioned for the calculation of interference patterns would be far from being "entirely legitimate", as the referee has it. Although this doubt is not excluded as a matter of principle, in a series of steps of critically checking the experiment this particular step would come rather late. "Double checking and questioning scientific background assumptions" not referring to accepted fundamental theories, however, is a completely different matter. Of course, I never meant to deny the legitimacy of a critical scientific discussion of assumptions of this kind on level zero of philosophical radicality.

objects that our mature and well-confirmed theories about the pertinent domain postulate, based on our observations of macroscopic objects? A positive answer to this question is (roughly) the position of the scientific realist. Someone who denies the legitimacy of this step to a realist interpretation of well-confirmed mature theories is a scientific anti-realist, or instrumentalist. Clearly, the question about the *general* legitimacy of realist interpretations of well-confirmed mature theories is more radical than the zero level question about the legitimacy of the realist interpretation of a given *individual* theory. The former question is a philosophical question, the latter a scientific one. Clearly, on level zero, i.e., in the scientific context, the general legitimacy of realist interpretations of theories (under appropriate conditions) is taken for granted. In other words, the general *philosophical* doubt about realist interpretation articulated on level one does not come into play in the scientific practice on level zero.[3] The situation is similar to the situation we are confronted with by "the" problem of induction. Philosophers (since Hume) have asked the question of the legitimacy of inductive generalizations in general (level one). Scientists, by contrast, take the possibility of inductive generalization under appropriate conditions for granted and ask in any particular case, whether the conditions for a valid inductive generalization are met (level zero).[4]

One can push philosophical doubt even beyond level one of philosophical radicality, although this is much less fashionable in current philosophy of science. The main assumption of the first level of philosophical radicality is that we have knowledge of observable macroscopic objects. If one is a scientific anti-realist on the first level, one may extend one's doubt about the epistemic accessibility of unobservable objects to observable objects as well (this is of course but one route to this higher level of philosophical radicality). Thus, on this second level of philosophical radicality, the existence of and our epistemic access to macroscopic observable objects is questioned. Roughly, this is the level of philosophical radicality on which sense data based philosophies, Kant, perspectival realism, and model-dependent realism, among others, operate.[5] These philosophies question the

[3]I note in passing that in the history of philosophy, others have seen this difference also. For instance, Edmund Husserl denoted it as a difference between the "natural standpoint" and the "critical epistemological standpoint"; see Husserl (1967 [1922], §§ 27ff).

[4]With respect to the scientific realism debate, the above distinction between levels zero and one of philosophical radicality has been articulated somewhat differently in Magnus and Callender (2004). They distinguish "retail arguments for realism (arguments about specific kinds of things such as neutrinos, for instance) from wholesale arguments (arguments about all or most of the entities posited in our best scientific theories)" (321). Clearly, this distinction is very similar to the one proposed above. However, what is missing from my point of view in Magnus and Callender's version of the distinction is the explicit reference to the correlated difference of epistemic stances, here called different levels of philosophical radicality. Only the difference in the epistemic stances reveals the possibility to defend seemingly inconsistent positions at the different levels; see below.

[5]For perspectival realism, see, e.g., Giere (2006); for model-dependent realism, see, e.g., Hawking and Mlodinow (2010). It seems to me that these two positions are essentially identical.

givenness, or pure object-sidedness, of unitary observable macroscopic objects and propose to investigate the constitution of these objects, i.e., the contribution of subject-sided elements. Obviously, different philosophical positions may result from this questioning the apparently unquestionable pure object-sidedness of observable things. Pushing philosophical radicality even further, one may reach Cartesian skepticism (from which position it seems very difficult to move anywhere).

It should be noted that the different levels of philosophical radicality are not uniquely defined. Neither do I claim that a certain level structure of philosophical radicality in one area of philosophy can be immediately transferred to another area, say from philosophy of science to ethics. There, the levels of philosophical radicality may take on forms different from the ones in philosophy of science. The essential point is that at some level n, certain things are taken for granted, whereas at level $n + 1$, they are questioned. To move from one level to another, i.e. to participate in discourses situated at different levels, is not inconsistent.[6] Each level determines a certain discourse by fixing certain things as given and beyond dispute – for the sake of argument, or of conviction. A discourse determined in this way may be interesting or uninteresting, depending on one's goals and convictions. For instance, in order to understand certain every day or certain scientific practices, one should be aware of being at the zeroth level, whereas certain philosophical questions necessarily involve a move to a higher level of philosophical radicality. As I have illustrated above by the example of Steven Hawking, the same person can work at both levels – as all antirealist philosophers do when it comes to normal everyday affairs, were they typically do not doubt the existence and cognizability of observable objects.

However, individual philosophers and scientists strongly differ in their willingness to engage with the various levels of philosophical radicality. The higher the degree of philosophical radicality, the further away from common sense one moves. If one uses the adherence to common sense as an argument against one's engagement with one of the levels beyond level zero, one should be conscious about this argument's persuasive force. It may be a convincing argument for those who think that with common sense one is epistemologically on a safer ground than with any mode of philosophical questioning that a particular higher level of philosophical radicality involves. However, for those defending the practice of philosophy on a higher level, the accusation of a deviation from common sense is certainly not persuasive. Quite on the contrary: for asking philosophical questions on a certain level of philosophical radicality above level zero is nothing but questioning certain common sense presuppositions. Thus for those philosophers, the refusal of engaging with that level of philosophical radicality is nothing but a refusal of philosophy itself.[7]

---

[6]Some defenders of common sense realism appear to assume the inconsistency of level zero and level one. See, for example, Richard Dawkins: "Show me a cultural relativist at thirty thousand feet and I'll show you a hypocrite": Dawkins (1995, 31–32).

[7]See, e.g., Rowbottom (2011) against the scientific realist philosopher Howard Sankey.

In the following, we will move beyond level zero. I shall investigate two arguments or strategies, respectively, which are standardly used in the defense of scientific and/or structural realism: the "miracle argument" and the "selective strategy".

1.3 The Miracle Argument

One of the most important arguments for scientific realism starts from an uncontroversial observation: science has been very successful repeatedly in producing novel predictions. The cases that are relevant for the argument must be described more carefully. "Predictions" in the given context are not necessarily predictions in the temporal sense, but are statements about observable putative facts that are derived from a certain hypothesis or theory. Typically, pertinent antecedent conditions and possibly other assumptions have to be included in the premises of the derivation. The "novelty" of the prediction means in the given context that the predicted data have not been used in the construction of the theory. For clarity, sometimes the expression "use-novel predictions" is used.[8] Here are two examples. In 1916, Einstein predicted the existence of gravitational waves as a consequence of his General Relativity Theory (GRT) (Einstein (1916), with corrections in Einstein (1918)). Gravitational waves were not used in the construction of GRT and were thus a use-novel prediction. Secondly, in 1927, Heitler and London derived from the newly developed quantum theory the existence of the covalent bond between hydrogen atoms (Heitler and London 1927). The covalent bond was well known at the time but unexplained in terms of physics, and it was not used in the construction of quantum mechanics. In this sense, the existence of the covalent bond was a use-novel prediction of quantum mechanics.

The question is, how are these use-novel predictions possible? How does a theory acquire the capability of predicting novel facts that the theory was not designed for? What exactly are the resources of a theory for such predictions? In other words, how can this particular success of theories be explained? Scientific realists have a plausible answer to these questions. Theories can produce correct use-novel predictions if they are approximately true, i.e., if their theoretical terms refer to real entities and if they get the properties of these entities at least approximately right. Thus, approximate truth of theories is *sufficient* for correct use-novel predictions. However, according to the scientific realist, approximate truth is also *necessary* for correct use-novel predictions. The reasoning is that without approximate truth of a theory, it is just incomprehensible how it could be capable of producing use-novel

[8] According to Schindler (2008, 266), the term "use-novelty" has been introduced by Deborah Mayo in Mayo (1991, 524). The concept of use-novel predictions, as opposed to temporally novel predictions, was apparently introduced by Zahar and Worrall in the 1970s and 1980s: see Worrall (1989, 148–149).