THE FRONTIERS COLLECTION

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The books in this collection are devoted to challenging and open problems at the forefront of modern science, including related philosophical debates. In contrast to typical research monographs, however, they strive to present their topics in a manner accessible also to scientifically literate non-specialists wishing to gain insight into the deeper implications and fascinating questions involved. Taken as a whole, the series reflects the need for a fundamental and interdisciplinary approach to modern science. Furthermore, it is intended to encourage active scientists in all areas to ponder over important and perhaps controversial issues beyond their own speciality. Extending from quantum physics and relativity to entropy, consciousness and complex systems—the Frontiers Collection will inspire readers to push back the frontiers of their own knowledge.

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Shyam Wuppuluri · Francisco Antonio Doria
Editors

The Map and the Territory

Exploring the Foundations of Science, Thought and Reality

Foreword by Sir Roger Penrose and
Afterword by Dagfinn Føllesdal

Springer

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Foreword

This volume provides a wonderful collection of essays by very distinguished scientists, mathematicians and philosophers. We find here their numerous and very different deep and individual conceptions of the relationship between the actual world we live in and how we perceive and understand that world. The variety presented here is stunning in its breadth and diversity of outlook.

In accordance with such diversity, it is difficult for me to comment without interposing something of my own personal viewpoints which have come about from a lifetime's study of mathematics and the foundations of physical theory. It is indeed hard for me not to be hugely influenced by both the extraordinary subtlety and power of the mathematical structures that have been developed over many centuries, where not only is the precision inherent in these mathematical edifices breathtaking when the theory works well, but also in such theories there revealed a supreme beauty in the coherence and frequent unexpected applicability that one finds in these physical laws when they are at their most successful.

We now have, for example, clocks that are so precise that had they been started at the time of the Big Bang they would still remain true to within a second. But what do we mean by true? This refers to an internal consistency between theory and observational facts whenever it becomes possible to bring the two together. Much of this precision comes about from those two great revolutions of twentieth-century physics, namely general relativity and quantum mechanics, both of which theoretical constructions are confirmed in observation to an extraordinary degree. The clocks just referred to, for example, depend upon a deep relevance of the two most important formulae of twentieth-century physics, namely Albert Einstein's central formula of relativity theory $E = mc^2$ and Max Planck's foundation stone of quantum mechanics $E = h\upsilon$. The first states the equivalence of energy with mass and the second, the equivalence of energy with frequency, and put together we get the equivalence of mass with frequency, whence stable massive particles must themselves possess oscillatory frequencies of incredible precision. Yet, these two great theories do not sit comfortably together. Indeed, in a deep sense, Einstein's general relativity is technically inconsistent with the foundational tenets of quantum theory.

Should one take the view that they are just our best way of understanding the world in its largest scales and in its smaller scales, where there might be no reason to expect that some overarching and internally consistent mathematical scheme might be waiting in the wings, someday to be discovered to encompass both as limiting approximations? My own view is certainly that there must be something of this nature, and that ultimately we may be fortunate enough to come across such an overall mathematical framework which will override our current disparate attempts to account for the actions of the knowable universe—in principle at least.

As our current theories stand, there is a particular issue about quantum mechanics that is not shared by general relativity. In the latter, there appears to be a well-established ontology whereby the mathematical models that we try to construct consistently with the equations of the theory can present us with allowable pictures of what we may be able to refer to as candidates for inhabitants of 'the real world'. In quantum mechanics, what we are presented with is something very different where there is little agreement between different proponents of what the theory might mean. Is the wavefunction real? If so, does it satisfy the unitary equation of Schrödinger? If so, how does this address the issue of 'Schrödinger's cat' whose 'real' existence would be described as being in a superposition of death and life? Or is the very wavefunction a mere mental construction providing us with just a way of calculating probabilities of something which then becomes real—or what? In my view, there are strong reasons for taking the standpoint that there must be some form of reality in the wavefunction but that this does not always satisfy Schrödinger's actual equation, and something different then comes about in 'reality' from time to time? Perhaps, this 'really' happens only as soon the space–time curvatures of Einstein's gravitational theory begin to impinge on the structure of quantum mechanics. Might such a scheme be needed before an overall ontological consistency can be provided for quantum theory?

What about determinism? Current quantum mechanics, in the way that it is used, is not a deterministic scheme, and probabilistic behaviour is taken to be an essential feature of its workings. Some would contend that such indeterminism is here to stay, whereas others argue that there must be underlying 'hidden variables' which may someday restore a fully deterministic underlying ontology.

Personally, I do not insist on taking a stand on this issue, but I do not think it likely that pure randomness can be the answer. I feel that there must be something more subtle underlying it all. What view we take about the ontology of the world seems to be intimately tied up with what equations, or other mathematical constrictions our theories define for us. It is my view that many of the puzzles that people have in relating the formalism of quantum mechanics to the behaviour of the physical world come about from a committed belief in the universal correctness of the quantum formalism as it stands today. To me, there is a profound question about this widely held belief among established physicists that one should not monkey with this formalism and take what it says to be an unquestioned truth. It is this that, in my view, leads to many of the difficulties that people have with providing a fully consistent ontology for quantum mechanics.

In this volume, you will find many alternative positions on this and many other issues that arise in relation to the whole concept of 'ontology' and what it may actually mean. Moreover, the tests that are applied to physical theories in order to see whether they are consistent with nature are often extraordinarily refined. Much of our experience of the world itself is in circumstances where behaviour can be consistent without expectations mainly because we have seen such things frequently before. We are unlikely to test the behaviour of a spilled glass of orange juice by delving into the detailed equations that physics has presented us with. Instead, we tend to have a faith that if such a situation were studied in detail using all the equations that we believe to be relevant, then there would be consistency with what we observe. Is this faith justified? Probably in the case of a glass of orange juice, this is so. But how about situations when it comes to the behaviour of biological systems and their growth patterns? In the case of animals, and how they might behave in the face of different external circumstances, do we fully trust our equations? How about the behaviour of a human brain? Do we have the same faith that those laws that serve us so well with inanimate entities will serve equally in the case of human behaviour? Might there be something different when it comes to consciously controlled actions? Might we need to extend our physical pictures to something beyond the kind of mathematical theory that has worked so well for us so far?

Clearly, there are many questions about what reality might be and whether or not our physical theories are close to providing a universal picture of how the world operates. These theories are—or at least have been so far—mathematical theories with reasonably sound underpinnings of consistency, despite some puzzling issues of their ontological status. If the mathematics ever comes to fit the behaviour of the world in a way which appears to be absolutely precise, would we choose to identify actual reality with well-prescribed terms in this mathematical formalism? Could we live with a picture where we and all our surroundings are simply parts of the Platonic world of purely mathematical abstractions? A view is not uncommonly put forward that the world is, in some sense, simply a computational 'simulation', like the running of a computer program. This is a viewpoint that I find hard to relate to. If the operation of our universe is merely a simulation, then what is the 'thing' that it actually simulates? Our current technology, which depends so strongly upon the actions of computers, seems to render such a picture plausible. But that is not my own picture of how our universe can operate. Mathematics, yes, it must deeply underlie the workings of the world, but that does not imply that the world operates in an entirely computational manner. There is far more to mathematics than that.

Oxford Roger Penrose
August 2017

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[1] But it is not blank! It has some text! The map is not the territory.

Preface

After we came out of the church, we stood talking for some time together of Bishop Berkeley's ingenious sophistry to prove the nonexistence of matter, and that everything in the universe is merely ideal. I observed that though we are satisfied his doctrine is not true, it is impossible to refute it. I never shall forget the alacrity with which Johnson answered, striking his foot with mighty force against a large stone, till he rebounded from it—I refute it thus.

—Life of Samuel Johnson, James Boswell

The irony of life is that it is lived forward but understood backward

—Soren Kierkegaard

Ob nicht natur zuletzt doch ergründe?

—Wolfgang Von Goethe

In this volume, some of the world's leading thinkers come together to expound upon the topic of the map/territory distinction in the foundations of science, the process of thought and even reality itself, whatever that may be. Science longs for simplicity. As Einstein once remarked, 'everything should be made as simple as possible, but not simpler'. One of the chief goals of science is to find a minimalistic set of equations that can describe all the happenings in the universe, so short that a person sitting at a cafe, sipping *caffè macchiato*, *in angello cum libello*, can scribble it down on the back of his coffee bill. These bite-sized equations hold within themselves a myriad of complex interrelationships between various areas of knowledge and therefore also with the real world. Knowledge and ignorance, as ever, share a *ménage-à-trois* relationship with thought. The more we know, the more we realise that there is to know, and the more we realise how much we do not know.

To think is to represent, whatever the nature of such representation. There is undoubtedly a deep connection between the name and that which is named, phonetics and script, a picture of a person and the person it shows, thought and the object of thought, a map of Vienna and Vienna itself, a finger pointing at the moon and the moon, etc. We all grew up reading those classic stories of romance, in which a troubled princess trying to escape from the kingdom stares endlessly at the picture of an imaginary prince, and lo and behold, the prince materialises from the picture and saves her! Too good for a fiction plot and too bad for science.

Representations are handy and tempting, and they come so naturally to us that we quite often end up committing the category error of over-marrying the representation with what is represented, so much so that the distinction between the former and the latter is lost. This is a form of intellectual *harakiri* that prevents us from understanding the subject. 'If all we have is a hammer, everything looks like a nail', as the saying goes. Similarly, if all we have is a map, everything looks like a territory. Sometimes, there may be no territory corresponding to our map, in which case our map is just a convenient representational tool, like a mnemonic, but a plethora of paradoxes and inconsistencies surface when we consider the most successful abstractions (maps) to be a part (or an attribute) of the real world.

Therefore, it is imperative for a student or a researcher of science to differentiate between the computational tool and what it computes, to distinguish the map from the territory it represents. 'The map is not the territory', remarked Alfred Korzybski. There are multitudes of maps that we use to 'represent' the reality out there. They differ both in form and substance. The scientist in this sense resembles a cartographer. Only a cartographer knows how hard is it to represent a map of the earth on a sheet of paper. Every step towards perfecting the map involves a sacrifice—adding some feature to the map that does not have any intuitive or direct correspondence with the territory or ignoring many complexities of the territory.

For instance, consider an apple. One can apply a name and a price tag to it and study the economics and geography of the commodity. Or an apple may just be a collection of sensory perceptions like taste, colour, touch, etc., that lead us to the basic idea of an apple. Or one can describe it as a biological system and apply genetics and the other formalisms of biology to study it. Or model it as a point-like particle and apply Newtonian mechanics to it. Or see it as a point in 4D space–time that instantiates an event and apply the principles of relativity to it. Or see it as a vast collection of sub-atomic particles obeying the laws of quantum mechanics, quantum field theory, string theory and so on.

Which one of these is the **apple that's out there**? Or is there an apple out there, apart from these maps (notions)? Here, we are concerned with the epistemology/ontology distinction. Can we transform one map into the other? Or is there a global map that can simulate every other map under some constraint? Do all of these maps co-exist? In the same vein, to what extent are our scientific maps accurate in portraying their corresponding territory? What about the things like numbers, sets, classes and functions? What about space, time, fields and operators? Are they a part of our map (computational/visualizational tools) or are they part of the territory (reality)? If two maps cannot be integrated, is this a limitation of our scientific cartography or is it the nature of the underlying territory itself that prevents us from such an attempt? Foundational questions of this sort play an important role in science, especially in modern physics (grand unified theories). It is safer to let the gaps remain as gaps while we let our maps remain as maps, rather than giving in to the seemingly seductive approach of trading in our understanding and intermingling maps with territory to fill in the conceptual gaps—however, much this may comfort us and appeal to our tastes!

The eminent philosopher W. V. O. Quine quotes Otto Neurath in his magnum opus 'Word and object', *'Neurath has likened science to a boat which, if we are to rebuild it, we must rebuild plank by plank while staying afloat in it. The philosopher and the scientist are in the same boat…*' We can further imagine this particular vessel to be the '*Ship of Theseus*', which at every point has to maintain consistency with the established truths and in some 'sense' preserve its structure. But is this really the case? Modern science, with its numerous interconnections between so many different fields, is reminiscent of the interconnections between the neurons in our brain. There are also meta-maps—so to speak—which serve as mortar between the different maps. It is almost impossible to speak of any subject or map in isolation, or establish a hierarchy of fields to show what arises from what. Everything co-exists. It is the whole that gives meaning to its parts, and the parts that give meaning to the whole.

Beneath all the richness of these maps is our consciousness, which colours them and in turn gets coloured by them. Our thoughts are so densely connected with each other that it is impossible for us to step twice into the same metaphorical river of thoughts. As Sartre says, in every attempt to enter consciousness, we are seized by a whirlwind and thrown back outside. We then turn to language, our only hope, which also plays an important role in the mapping process. All the categorization our cognition exercises bears an intricate relationship with language. For instance, how is it that the patterns of tilings we see become a tiling of patterns? Consider also the statement: 'There are three red balls in the urn'. Is it that the property of ballness is substantiated thrice? Or is it the property of threeness that is substantiated by a set of three red balls? Or is it that the property of redness is thrice substantiated by ballness? Or conversely? Which attribute is a part of reality and which one is not? Is this a situation where our language (*façon de parler*), which is playing Wittgensteinian games here, would put an end to these a priori/a posteriori disputes?

Above all, who are Homo sapiens but a bunch of evolved apes, selected by the Darwinian selection process and nurtured by nature over thousands of generations? Evolution has definitely contributed to our understanding of the world, by giving us brains and language, in a direct or indirect manner. How far does nature qua evolution control the very modalities that we use to picture it? For instance, we cannot see the third dimension in a straightforward manner, in the way we see two dimensions. Neither can we fly in the air like birds. We cannot drink and talk at the same time. Neither can our skin harness light energy from the sun, as plants do, to provide fuel for our everyday lives. Nature has blessed each of its species with their own modalities, allowing them to establish their own relationship with the reality they perceive and interact with. While the above limitations are physical in nature, we assume our brain is free to ponder anything, and that no one can imprison our imagination. To some extent, we have overcome these physical limitations and taken several steps ahead with a sense of victory, seeing the third and even fourth dimensions using technology, and even getting hold of infinite dimensions with the help of induction and advanced mathematics. We have also discovered that we do

not always need wings to fly, just as we do not necessarily need legs to walk. This notion of abstraction, abstracting walking from legs and flight from wings, has given us cars and aeroplanes. But are there things we would have thought otherwise had we been granted different sensory systems? We definitely do not perceive the world the way (say) a goldfish perceives it. Are there truths that a goldfish alone knows and that perhaps we can never know? As Wittgenstein once said, 'If a lion could speak, we wouldn't be able to understand it'. So evolution definitely fences in the very way we think and reveals to us only those aspects beneficial for our survival. But the question is, to what extent? Is there a way out of the metaphorical Platonic cave erected around us by the nature?

Amidst this pessimistic and chaotic mass of questions, is there any chance of finding clarity and order?

It is hoped that the articles in this collection will be of some help here, authored by intellectual giants who can provide us with deep insights into the nature of maps and territories. When this volume was planned, it seemed natural to organise the articles into sections to facilitate understanding, and in the hope that a global meaning will emerge from these contextual viewpoints when we finally come to join the dots. We have thus divided the volume according to field, namely philosophy, physics, mathematics/computer science, biology/cognitive science, and a miscellaneous section which includes literature and geography. Every article in each field deals with the underlying issue of the map/territory distinction and addresses the problem from its own point of view, in the context of that particular field. The authors have invested considerable time and energy to make the articles accessible both to researchers and to those with only a rudimentary knowledge of the subject.

Is the map the territory? Are we trying to answer a question or question the answer? Join us on this journey if you would like new perspectives on questions like these.

Juhu, Mumbai, India Shyam Wuppuluri

Acknowledgements

We are but dwarfs mounted on the shoulders of giants, so that we can see more and further than they; yet not by virtue of the keenness of our eyesight, nor through the tallness of our stature, but because we are raised and borne aloft upon that giant mass.

—Bernard of Chartres

The giants who have contributed to this volume have helped us to see further than we could ever see. I would like to return a part of their favour by thanking them for going out of their way, investing their valuable time and making this piece of work possible. Assembling a volume with the length and breadth of this is no cakewalk. Let me begin thanking everyone who have helped me do so. I shall do this in a chronological way.

While the overall structure and contents were in place, with 40 authors on board but still moored in the harbour, I sought a co-editor for feedback. I am eternally grateful to my co-editor, an erudite scholar, Prof. Francisco Antonio Doria and his lifelong collaborator and genius Prof. Newton Da Costa, for the excitement, support, suggestions, pertinent feedback and kindness they showered me with, at various stages, since the volume's inception. Such debts as this cannot be cleared just by thanking. I hope their friendship and collaboration will continue to inspire many others, while they continue to spread goodwill to those around them. Dr. Angela Lahee, editor and founder of the Frontiers Collection, has been exceptionally kind right through the production process, and played the role of a stake, maintaining the structure of this intellectual tent against the stormy desert night. Her timely editorial support, well-aimed criticism, support, finesse, and immense expertise are warmly acknowledged herewith.

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administrator at Oxford, for her kind cooperation and help. When I first approached Prof. Dagfinn Follesdal, student of W. V. O. Quine, he not only responded positively, but also went to the trouble of going through the other articles and leaving us with a beautiful afterword. I extend my most heartfelt thanks to him for this warm gesture.

I feel a little guilty that I cannot mention each author here, but I would like to thank them all wholeheartedly for their efforts, and especially those who generously and patiently incorporated feedback and customised their article, despite their pressing academic commitments. I thank Prof. Gregory J. Chaitin and his wife Prof. Virginia Chaitin for their kindest support, their contribution and more than anything for the unconditional love they have offered. I hope that the new phase of their life brings them great joy! I would like to then thank Prof. Ian Stewart, Prof. Barry Dainton for their efforts and support. I would also like to thank Prof. John R. Searle and Prof. Tyler Burge for their time, patience, interaction and support. I also thank Prof. Joseph Kouneiher for his contribution. I acknowledge his humility, intellect and his kindness herewith.

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I would like to thank Prof. Douglas Hofstadter and Prof. Daniel C. Dennett, who inspired me and so many others, endlessly through their books and their personality. I am also thankful to Prof. John Stachel for the continued kindness and encouragement that he has provided me with. Finally, I would like to thank all those who have shown kindness towards me, as well as those who did not, for each in their own way has contributed to my betterment. I, like Lazarus, have managed to survive so far on the breadcrumbs of love and kindness that have fallen from the table of rich—rich in heart. The boon or the curse of existence, I truly believe, lies in such love and kindness. This reminds me of something I wrote some time ago:

"Where does the fault lie? In our Stars?" asked the puzzled boy of his grandfather, a retired physicist. "Or is it in space and time itself?" he continued. "Why is it that it takes forever to see that someone is good? And only an instant to prove that someone is bad! Is time the culprit here? Is it space that prevents two people being together emotionally or physically?"

"No!" his grandfather exclaimed, patting the boy on the shoulder. "The fault is neither in our stars, nor in space and time. It's in our love, which weaves the very fabric of existence. Love, which is the alpha and the Omega. Love, which is the journey and the destination."

Juhu, Mumbai Shyam Wuppuluri

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About the Editors

Shyam Wuppuluri is working as a Research Associate in R. N. Podar institute. As a computer science graduate, he has a long-standing interest in various areas of philosophy, theoretical physics, mathematics and cognitive science. Prior to this, he edited the volume 'Space, time and limits of human understanding, foreword by John Stachel, afterword by Noam Chomsky', which was published in Springer—the frontiers collection, 2016.
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Francisco Antonio Doria is a Brazilian physicist. He is a Professor Emeritus at the Federal University of Rio de Janeiro, where he currently teaches on the foundations of economic theory at the graduate School of Engineering (UFRJ COPPE). He has a B.Sc. in chemical engineering and a Ph.D. in mathematical physics (under the guidance of Leopoldo Nachbin). He has made contributions to the gauge field copy problem in quantum field theory and proved with Newton da Costa several incompleteness theorems in mathematics, physics and mathematical economics, including the undecidability of chaos theory. He is a member of the Brazilian Academy of Philosophy, a Senior Fulbright Scholar at Stanford University, 1989–1990, and a visiting researcher at the mathematics department, University of Rochester, 1979–1981. He thinks of himself as a philosopher and literary scholar with a humanist education, and has had as students Marcelo Gleiser and José Acacio de Barros, among other noted researchers. He likes to trace his interdisciplinary interests to a seventeenth-century relative, the noted Portuguese writer Father Antonio Vieira (1608–1697).
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