

Bookshelf

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Trick or Truth? The Mysterious Connection Between Physics and Mathematics

By Anthony Aguirre, Brendan Foster, Zeeya Merali (eds)

Springer

One of the most intriguing works in the philosophy of science is Wigner's 1960 paper titled "The Unreasonable Effectiveness of Mathematics in the Natural Sciences". Indeed the fact that so many natural laws can be formulated in this language, not to mention that some of these represent the most precise knowledge we have about our world, is a stunning mystery.

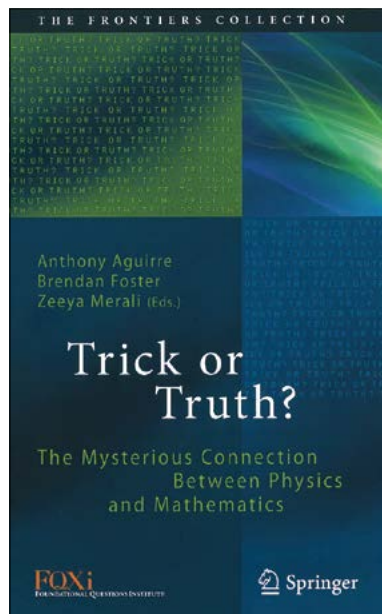
A related question is whether mathematics, which has largely developed overlapping or in parallel with physics, is constructed by the human mind or "discovered". This question is worth asking again today, when modern theories of fundamental physics and contemporary mathematics have reached levels of abstraction that are unimaginable from the perspective of just 100 years ago.

This book is a collection of essays discussing the connection between physics and mathematics. They are written by the winners of the 2015 Foundational Questions Institute contest, which invited contributors – from professional researchers to members of the public – to propose an essay on the topic.

Since it appears primarily as a subject of the philosophy of science rather than of science itself, it is not a surprise that there are conflicting viewpoints that sometimes reach opposite conclusions.

A significant point of view is that the claimed effectiveness of mathematics is actually not that surprising. This is because we process information and generate knowledge about our world in an inadvertently biased way, namely as a result of the evolution of our mind in a specific physical world. For example, concepts of elementary geometry (such as straight lines, parabolas, etc) and the mechanics of classical physics are deeply imprinted in the human brain as evolutionary bias. In a fuzzy, chaotic world, such naive mathematical notions might not have developed, as they wouldn't represent a good approximation to that world. In fact, in a drastically unstructured world it would have been less likely that life had evolved in the first place, so it may not seem such a surprise that we find ourselves in a world largely governed by relatively simple geometrical structures.

What remains miraculous, on the other hand, is the effectiveness of



mathematics in the microscopic realm of quantum mechanics: it is not obvious how the mathematical notions on which it is based could be explained in terms of evolutionary bias. Actually, much of the progress of fundamental physics during the last 100 years or so crucially depended on abandoning the intuition of everyday common sense, in favour of abstract mathematical principles.

Another aspect is selection bias, in that failures of the mathematical description of certain phenomena tend simply to be ignored. A prime example is human consciousness – undoubtedly a real-world phenomenon – for which it is not at all clear whether its structure can ever be mapped to mathematical concepts in a meaningful way. A quite common reductionist point of view typical of particle physicists is that, since the brain is essentially chemistry (thus physics), a mathematical underpinning is automatic. But it may be that the way such complex phenomena emerge completely obfuscates the connection to the underlying, mathematically clean microscopic physics, rendering the latter useless for any practical purpose in this regard.

This raises the issue of the structure of knowledge per se, and some essays in this book argue that it may not necessarily be hierarchical but rather scale invariant

with some, or many, distinguished nodes. One may think of these as local attractors to which "arrows of deeper explanation" point. It may be that only locally near such attractors does knowledge appear hierarchical, so that, for example, our mathematical description of fundamental physics is meaningful only near one particular such node. There might be other local attractors that are decoupled from our mathematical modelling, with no obvious chains of explanation linking them.

On a different tack, a vehemently dissimilar and extreme point of view is taken by adepts of Tegmark's mathematical universe hypothesis, which has been directly addressed by various authors. This posits that there is actually no difference between mathematics and the physical world, so the role of mathematics in our physical world appears as a tautology.

Surveying all the thoughts in this collection of essays would be beyond the scope of this review. Suffice it to say that the book should be of great interest to anybody pondering the meaning of physical theories, although it appears more useful for scientists rather than for the general public. It is not an easy read, but the reader is rewarded with a great deal of food for thought.

• Wolfgang Lerche, CERN.

Raw Data: A Novel on Life in Science

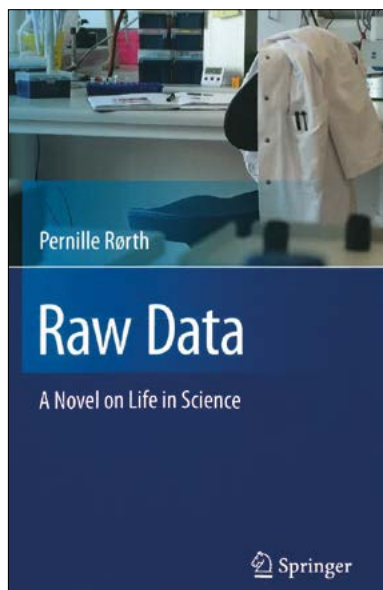
By Pernille Rørth

Springer

Raw Data is a scientific novel that explores the moral dilemmas surrounding the accidental discovery of a case of scientific misconduct within a top US biomedical institute.

The choice of subject is interesting and unusual. Scientific misconduct is not an unprecedented topic for scientific novels, but the focus is usually on spectacular frauds that clearly violate the ethos of the scientific community. This story depicts a more nuanced situation. Readers may even find themselves understanding, if not condoning, the conscious decision of one of the co-protagonists to cheat.

This character chooses to "cut a corner" out of fear of being scooped, to satisfy an unreasonably picky reviewer who had requested an additional control experiment that she deems irrelevant. The stakes for her career are huge because she is competing with other groups on the same research line, and publishing second would cost her a great deal academically. When a co-worker accidentally finds hints of her



fabrication and immediately alerts the laboratory's principal investigator, both find themselves in a bitter no-win situation. "Doing the right thing" has a significant cost, but any other option potentially entails far worse consequences for their careers and their reputations.

Along the way, the author illustrates vividly how people in research think, feel, work and live. Work-life balance in science, especially for young female researchers, is a secondary theme of the book. Overall, the portrait of academia is not a flattering one, but definitely faithful. As someone who works in high-energy physics, I learnt about day-by-day practices in the biomedical sector and how it differs from mine. Although the author focuses on her own area of the scientific environment, some descriptions of "postdoc life" are quite general.

This relatively short novel is followed by a long Q&A section with the author, a former biomedical researcher who left the field after some considerable career achievements. There she makes her opinions explicit about several of the topics, including the "publish or perish" attitude, work-life balance, scientific integrity, and what she perceives as systemic dangers for the academic research world.

Although the author clearly made an effort to simplify the science to the minimum needed to understand the plot (and as a reader with no understanding of microbiology I found her effort successful), I am not sure that a reader with no previous interest in science would be hooked by the

story. The book is well written, but the plot has a slow pace and, while Springer deserves credit for publishing it, the text contains many typographical errors.

Overall, I recommend the book to other scientists, regardless of their specialisation, and to the scientifically educated public who may appreciate this insider view of contemporary research life.

• *Andrea Giammanco, UCLouvain, Louvain-la-Neuve, Belgium.*

Books received

Gravity: Where Do We Stand?

By R Peron, M Colpi, V Gorini and U Moschella (eds)

Springer



This book, a collection of expert contributions, provides an overview of the current knowledge in gravitational physics, including theoretical and experimental aspects.

After a pedagogical introduction to gravitational theories, several chapters explore gravitational phenomena in the realm of so-called weak-field conditions: the Earth (specifically, the laboratory environment) and the solar system.

The second part of the book is devoted to gravity in an astrophysical context, which is an important test-bed for general relativity. A chapter is dedicated to gravitational waves, the recent discovery of which is an impressive experimental result in this field. The importance of studying radio pulsars is also highlighted.

A section on research frontiers in gravitational physics follows. This explores the many open issues, especially related to astrophysical and cosmological problems, and the way that possible solutions impact the quest for a quantum theory of gravity and a unified theory of the forces.

The book's origins lie in the 2009 edition of a school organised by the Italian Society of Relativity and Gravitation. As such, it is aimed at graduate students, but could also appeal to researchers working in the field.

Principles of Magnetostatics

By Richard C Femow

Cambridge University Press



This book aims to provide a self-contained and concise treatment of the main subjects in magnetostatics, which describes the forces and fields resulting from the steady flow of electrical currents.

The first three chapters briefly present the basics, including the theory of magnetic fields from conductors in free space and

from magnetic materials, as well as the general solutions to the Laplace equation and boundary value problems. Then the author moves on to discuss transverse fields in two dimensions. In particular, he covers fields produced by line currents, current sheets and current blocks, and the application of complex variable methods. He also treats transverse field magnets where the shape of the field is determined by the shape of the iron surface and the conductors are used to excite the field in the iron.

The following chapters are dedicated to other field configurations, such as axial field arrangements and periodic magnetic arrangements. The properties of permanent magnets and multiple fields produced by assemblies of them are also discussed.

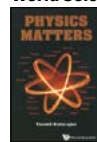
Finally, the author deals with phenomena where there are slow variations in current or magnetic flux. Since only a restricted group of magnetostatic problems have analytic solutions, in the last chapter numerical techniques for calculating magnetic fields are provided, accompanied by many examples taken from accelerator and beam physics.

Aimed at undergraduates in physics and electrical engineering, the book includes not only basic explanations but also many references for further study.

Physics Matters

By Vasant Natarajan

World Scientific



This book is a collection of essays on various physics topics, which the author aims at presenting in a manner that is accessible to non-experts and, specifically, to non-physics science and arts students at the undergraduate level. The author is motivated by the conviction that understanding fundamental concepts of other subjects facilitates out-of-the-box thinking, which can result in making original contributions to one's chosen field.

The selection of topics is very personal: some basic-physics concepts, such as standards for units and oscillation theory, are placed next to discussions about general relativity and the famous twin paradox. The author uses an informal style and has particular interest in dispelling some myths about science.

The final chapters cover topics from his area of research, atomic and optical physics, focusing on the Nobel Prizes assigned in the last two decades to scientists in these fields.

Even though the use of equations is kept to a minimum, some mathematics and physics background is required of the reader.