Book review by Palle E. T. Jorgensen

A review for the Math Intelligencer; of
Author: Penrose, Roger.
Title: The road to reality. A complete guide to the laws of the universe.
Publisher: Alfred A. Knopf, Inc., New York.
Book details: 2005. xxviii+1099 pp. ISBN: 0-679-45443-8.

It's always a delicate balance for a science book: Encyclopedic vs well focused on a unifying theme!

Penrose succeeds admirably in striking this balance: The book offers *a panorama of science*, and its goal is quite ambitious.

Yet the presentation is for the layman; it is engaging, and certainly not boring! Indeed, there are preciously few authors who manage to guide beginning students into serious scientific topics; especially when the aim is the big panoramic picture of science. The narrative flows well, and Penrose captured my imagination, and he held my attention through more than 1000 pages! I found the book inspiring, informative, and exciting. Penrose's writing is calm and composed. It is also honest about what mathematics and physics can accomplish. I count Roger Penrose among the outstanding scientists and expositors of his generation.

Aim and scope: I for one admire authors who succeed in communicating math to the layman; or the man and woman "on the street!" You can't argue with success. Since this book managed to hit a top spot on the amazon.com bestseller ranking, Penrose must surely be doing something right! And achieving popular appeal with a serious science book is so much more impressive. What author of math or of physics books would not envy this circulation size, or even a small fraction of it!

While this is a popular book, its goal is not modest: *A search for the underlying principles which govern the behavior of our universe.* And it raises the expectation level! Yet the presentation is modest when modesty is called for. It shouldn't surprise that the principles Penrose has in mind take the shape of mathematics (roughly the first half of the book), and physics (the good second half!)

Despite the grand and ambitious goal, I didn't feel cheated. But I was first skeptical as I took the book down from the shelf while browsing in my book store. As I read, I was pleased to find all the equations (not just hand waving!) Indeed the reader is first gently prepared with explanations for the technical sections. And when the formulas come, the reader is ready and will then *want* the mathematical equations. They aren't just dumped on you! Penrose's book is likely to help high school students getting started in science; and to inspire and inform us all. There is something for everyone: for the beginning student in math or in physics, for the educated layman/woman (perhaps the students' parents), for graduate students, for teachers, for scientists, for researchers; and

the list goes on. I believe Penrose proves that it is possible for one group of readers to be respectful of the needs of the other.

What is the book all about? It is both a big idea and especially it is a *unifying vision*! What laws govern our universe? How may we know them? How will this help us understand? Yet despite its vastness, the subject is well organized and it is fleshed out in the language of science.

A small sample of topics from the contents will give you a flavor. It is only a glimpse as there are 34 substantial and wide ranging chapters in all: The roots of science. An ancient theorem and a modern question. Geometry of logarithms, powers, and roots. Real and complex numbers. Calculus (A refreshing approach, I might add!) Functions and Fourier's vision. Surfaces and manifolds (plus calculus revisited!) Symmetry groups. Fiber bundles. Tensor bundles and tensor calculus. Cantor's infinity, Turing machines, and Gödel's theorem. The physics topics range from classical (Minkowski, Maxwell, Lagrange, and Hamilton) to modern, starting with Einstein's theory of relativity and the pioneers of quantum mechanics, Bohr, Heisenberg, Dirac, and Bohm. The modern topics further span quantum field theory, the Big Bang, cosmology, the early universe, gravity, supersymmetry, and they all merge into the final chapter "Where lies the road to reality?" Save the Epilog to the end!

I believe that this book does a great job in seemingly effortlessly moving the presentation from high school math to advanced topics (like Riemann surfaces, manifolds, and Hilbert space), and in physics (quantum theory, relativity, and cosmology). In fact, I am hard pressed to come up with an alternative book which in this way is even a close second. It is one of the very few science books of ambitious scope that is not viewed by students as intimidating. Penrose's clever use of Prologue and Epilogue engaged me as an uninitiated reader.

Since the book has by now become a best-seller, I expect that it worked well with other readers too. In fact, Penrose ads an element of suspense, and he manages to give the book the flavor of a novel. I can't begin to do justice to this book. Get it, and judge for yourself. I will also not give away the ending, other than saying that the title of the book is a good hint. And you will be able to form your own opinion, your own take, and to shape your own ideas and draw your conclusion. (You won't be spoon fed!) Like with all good and subtle endings to novels, this one can be understood and appreciated at several levels.

It will not surprise that one of Penrose's unifying themes is the attractive and pleasing geometric images that underlie both the *mathematics* (roughly one third of the book: modern geometry, Riemann surfaces, complex functions, Fourier analysis, visions of infinity), and the *physics*: Cosmology (the big bang, black holes), gravity, thermodynamics, relativity (classical and modern: loop groups, quantum gravity, twisters), and quantum theory (wave-particle duality, atomic spectra, coherence, measurements).

In the case of this book, a line-by-line overview of topics from the contents is misleading. A compelling feature of the presentation of topics from mathematics is that it is sprinkled with examples from physics. I wish this was done more in standard mathematics texts. Not only does this motivate and illuminate the concepts from mathematics, but it also serves to introduce ideas from physics.

For Penrose's grand ambition, this is essential; and as a pedagogical principle it works: This way the student will already have seen the areas of physics cosmology that will be resumed in the second part of the book.

Of the author's earlier research papers which are likely to have influenced the theme of the book I would mention [Pe65] in which Penrose proved a theorem which, under conditions which he called the existence of a trapped surface, established that a singularity in global space-time must necessarily occur at a gravitational collapse. Roughly, this is when space-time cannot be continued and classical general relativity breaks down. The present book searches for a unified theory combining relativity and quantum mechanics since quantum effects become dominant at singularities.

A second paper is [PeMa73] in which Penrose introduces his twistor theory; again an attempt at uniting relativity and quantum theory. Not surprisingly, a grand mathematical scheme designed at unification, and combining powerful algebraic and geometric tools!

While it is true that the book is about the laws of the universe, the reader familiar with other Penrose books will probably detect the contours of the author's prolific scientific activities spanning several decades, and including what is often called "recreational" mathematics. Reflecting on the versatility of Penrose's activities, it is worth remembering some these activities: Roger Penrose, a professor of mathematics at the University of Oxford, is known for his outstanding contributions to mathematics, to physics (relativity theory and quantum mechanics), and to cosmology. In addition, he has for decades pursued his interests in writing and in recreational math (e.g., the part of geometry known as tessellation (Penrose tiles), i.e., tile systems covering a surface with prescribed shapes, say kites and darts; what perhaps appear to be frivolous geometrical puzzles.) Yet this "hobby" produced sets of tiles that model 'quasi-periodic' patterns, a modern part of applied solid state physics: Some chemical substances are now known to form crystals in a quasi-periodic manner. These are patterns which at first glance seem to repeat regularly, but which on closer examination do not.

Readers interested in math illustration might find it intriguing that the author and his father are the creators of the so called Penrose staircase and the impossible triangle known as the tribar. Both of these "impossible" figures have been used in the work of Maurits Cornelis Escher in his creation of structures such as the waterfall where the water appears to flow uphill; and the building with impossible staircases which rises or fall endlessly, yet return to the same level.

The pictures: In fact, this semester, I was just teaching a geometry course, and I had a hard time presenting of Riemann surfaces in an attractive way. It's a subject that typically comes across as intimidating in many of the classical books: Take Herman Weyl's book, for example! I found these graphics in Penrose refreshing: Penrose's many illustrations are full of his own artistic touch. They are done with flair and are an antidote to having the flashy computer generated color-graphics and special effects that are typical in textbooks. Readers will probably relate better to illustrations with a personal touch: His clever use of shade helps the reader much better grasp core ideas, and appeal to our

imagination. And they are less intimidating: We sense that we ourselves would have been able to make similar pencil sketches. Or at least we are encouraged to try!

(A key to books for the classroom is student involvement. And the choice of exercises is essential. They help students (and other readers) become part of the discovery.) The pictures and the projects serve to bring to life the underlying ideas! Beginners might otherwise get lost in the math and the equations, or in the encyclopedic panorama of topics.

Is there something for a reviewer to complain about? Yes, the copy-editing of the book has been sloppy. But by now, there are websites with endless lists of tiny errors and omissions; names that are misspelled etc. This will probably bother a few mathematicians and other specialists. Given the length of the book, and the realities of science publishing, it didn't bother this reviewer. But it is a sad fact that modern day book publishers tend to skimp on copyediting, I don't really think that the various correction lists are alarmingly long. The publisher was probably reluctant to spend big bucks on a book with formulas. Little did they know (perhaps!?) that it would be a commercial hit. I hope that Penrose's book will encourage book publishers to give our subject the attention it so richly deserves.

Postscript: I came across Penrose's book in my bookstore by accident, and I was at first apprehensive: The more than 1000 pages, and the 3.3 pounds are enough to intimidate anyone. But when I started to read, I found myself unable to put it down. And I didn't: Bought it; and I had several days of enjoyable reading. I am not likely to put it away to collect dust either. It is the kind of book you will want to keep using, and to return to. Books like this are few and far between.

I expect that readers will react differently to the title, to the Prologue, to the math, and to the very ambitious scope.

Penrose's choice of title gave me associations (perhaps intended!) , bringing to mind Douglas Adams's amusing little book series, "Hitchhiker's guide to the galaxy". Here's a sample of sub-titles in Douglas Adams's hilarious books: "Life, the universe, and everything"; or "Mostly harmless". (Another association was a favorite series of mine of popular science books by George Gamow dating back to my childhood. Several of Gamow's books were recently reprinted, e.g., "Mr. Tompkins in Paperback".) I only mention my associations with these more lighthearted books to encourage readers to be realistic in their expectations. Judging by its top ranking at amazon.com when Penrose's book was released, it gained a rare entrance (for a science book) to the short list of popular best-sellers. This is truly impressive for a math book which is prolix, deep, thorough-going, and which at the same time tackles serious philosophical questions. While Penrose's book is indeed serious, I didn't mind a personal flair, and the warm sense of humor he brings to the subject. Only rarely do science books make me smile.

References

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