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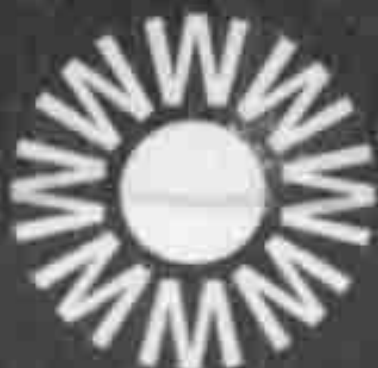
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# SCIENCIA

*mathematics, physics, chemistry,  
biology, and astronomy for all*



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*“... that which is below is as that which is above,  
and that which is above is as that which is below,  
to perform the miracles of the One Thing.”*

*The Emerald Tablet of Hermes Trismegistus*

SCIENCIA

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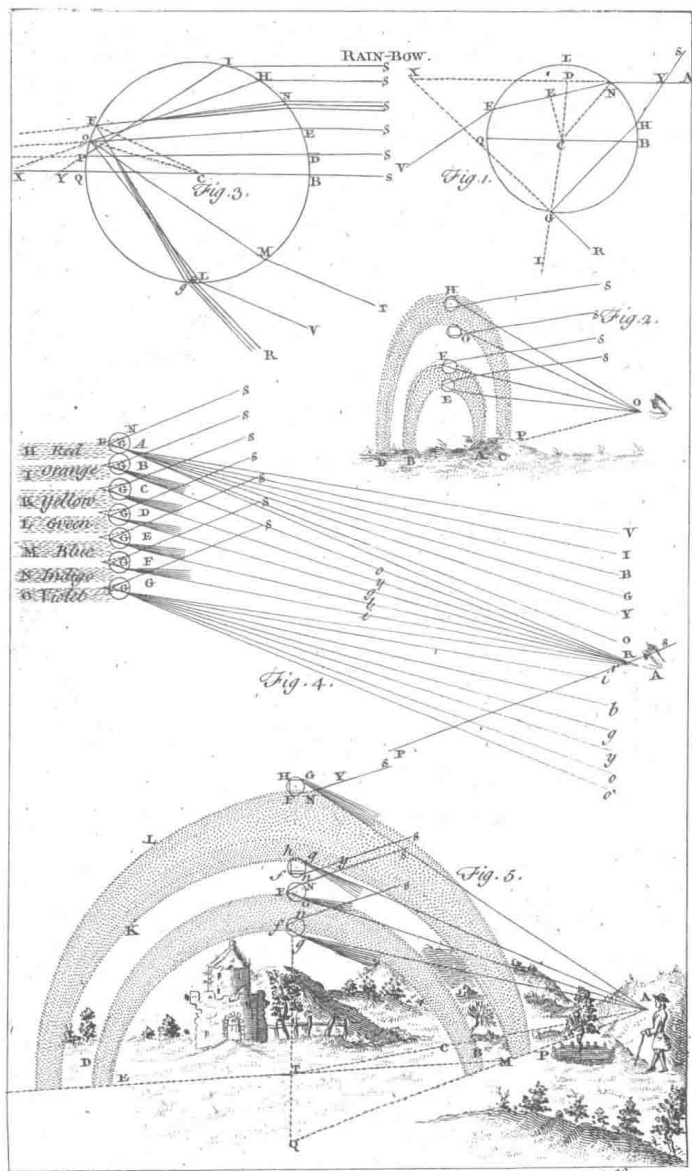
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*J. Jefferys sculp.*



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# EDITOR'S PREFACE

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This volume contains six popular scientific titles from the Wooden Books series. With some sections completely reworked and over 40 new pages, it summarizes much of the maths, physics, chemistry, biology, and astronomy that any budding scientist or layperson should know.

First up is Prof. Burkard Polster's wonderful book on Mathematical Proofs *Q.E.D.*, to remind us that some things are just plain obvious. Second is Dr Matthew Watkins' dense collection of *Useful Mathematical and Physical Formulæ*, a good test for anyone. For thirds, we turn to chemistry in Matt Tweed's fizzy guide to the Periodic Table of *Essential Elements*. Fourth is Dr Gerard Cheshire's lively treatise on *Evolution*, the journey of life on Earth. Fifth, to deepen our understanding of biology, we examine one organism in more detail in Dr Moff Betts' beautiful guide to *The Human Body*. Finally, in the sixth book, we turn our eyes to the skies and ponder the story of the incredible universe we inhabit and are a part of, in Matt Tweed's tour through *The Compact Cosmos*.

Illustration credits for *Scienzia* include: Cecily Kate Borthwick, Allan Brown, Vivien Martineau, David Goodsell, Caroline Ede, Joe McLaren, Dan Goodfellow, Will Spring, Simon Huson, NASA, Fermilab, and numerous engravers from centuries past. Other editors and designers have included Dr Peter Spring, Daud Sutton, Polly Napper, George Gibson, Mike O'Connor, and Dr Justin Avery.

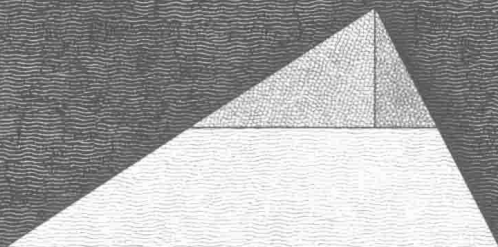
Apologies to purists but a mix of both UK and US spelling and punctuation has been used throughout this jointly printed edition.

Thanks to all, and happy reading.

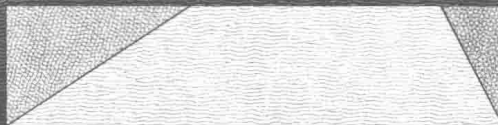
*John Martineau*



# BOOK I



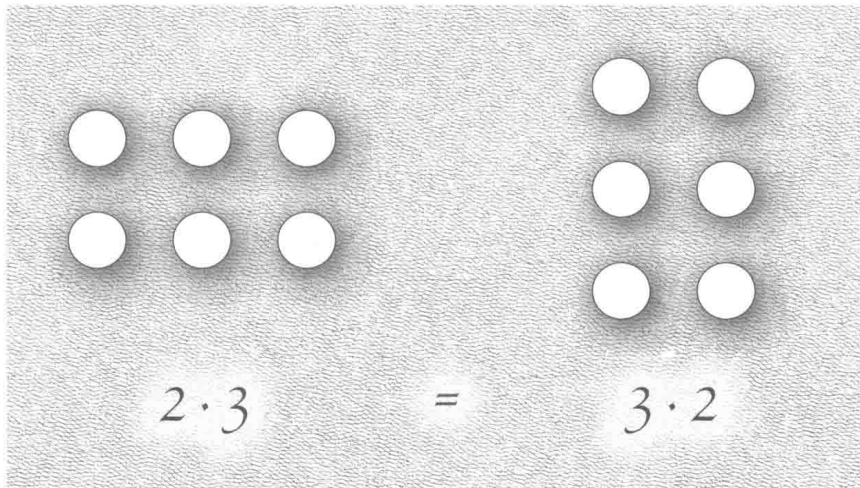
*area triangle = area rectangle =  $\frac{1}{2}$  base  $\cdot$  height*





# Q.E.D.

## BEAUTY IN MATHEMATICAL PROOF



*Burkard Polster*



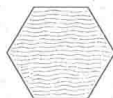
triangle



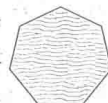
square



pentagon



hexagon

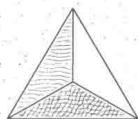
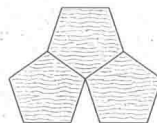
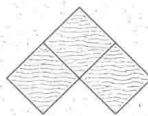
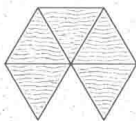
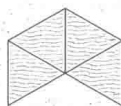
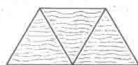


heptagon

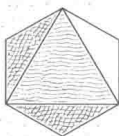


octagon

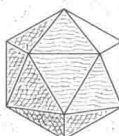
*A regular polygon is a convex figure with equal sides and angles. There are infinitely many regular polygons.*



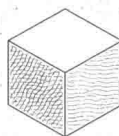
tetrahedron



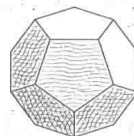
octahedron



icosahedron

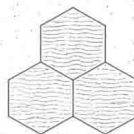
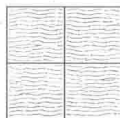
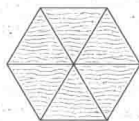


cube



dodecahedron

*A regular polyhedron is a convex body with identical regular polygons as faces and the same number of faces meeting at every corner. Shown at the top are the different ways of joining three or more identical regular polygons to a corner with space left to fold up into three dimensions. These possibilities of building spatial corners then can be shown to extend in a unique way to the famous five regular polyhedra.*



*The same simple reasoning shows that there are three tilings of the plane with identical regular polygons.*

# INTRODUCTION

---

There are some mathematical objects whose beauty everyone is able to appreciate. The regular polygons and polyhedra are good examples—these figures are surpassed in perfection only by the circle and the sphere. Then there is Pythagoras’ theorem, a cornerstone of the right-angled worlds we build for ourselves, and perhaps the conic sections which describe the orbits of celestial bodies.

Very few people appreciate more than some elementary aspects of mathematical beauty, much of it revealing itself only to mathematicians in the study and creation of intricately crafted proofs, barely within the reach of the most highly trained human minds.

As a mathematician, I declare that I have established the truth of a theorem by writing at the end of its proof the three letters Q.E.D., an abbreviation for the Latin phrase *quod erat demonstrandum*, which translates as “what had to be proved”. On the one hand, ‘Q.E.D.’ is a synonym for truth and beauty in mathematics; on the other hand, it represents the seemingly inaccessible side of this ancient science.

‘Q.E.D.’ can, however, also be found at the end of some simple, striking, and visually appealing proofs. This little book presents a journey through a collection of these wondrous gems, exploring the ideas behind mathematical proof on the way, written for all those who are interested in the beauty of mathematics hidden below the surface.

# TREACHEROUS TRUTH

*what proofs are all about*

---

In mathematics, as in the physical sciences, we may run an experiment or check a few cases to come up with a conjecture for a theorem. However, in mathematics experiments cannot replace proof, no matter how natural and obvious the conjecture is that they support. For example, the maximum number of regions defined by 1, 2, 3, 4, 5, and 6 points on a circle (*below*) are 1, 2, 4, 8, 16, and ... 31, and not 32!

Or, take the famous Goldbach conjecture which claims that every even number greater than two is the sum of two prime numbers as, for example,  $12 = 5 + 7$  or  $30 = 23 + 7$ . Although this conjecture has been checked for many millions of cases, unless a proof is found, we cannot be sure that the next case we check won't show that the conjecture is false.

Proofs should be as short, transparent, elegant, and insightful as possible. Our proof (*opposite top*) that the number  $0.999\dots$ , with infinitely many 9s, is equal to 1 is of this kind and its main argument can be easily adapted to convert any decimal number with one of those slightly worrying infinitely repeating tails into a number we are more comfortable with. The proof that the indented chess board cannot be tiled with dominos (*lower opposite*) is another example. Of course, the argument here applies to many other mutilated chess boards.

