

string theory including Michael Green and John Schwarz, were probing its mathematical boundaries.

Whether the mathematical approach eventually became too dominant, taking over in terms of academic recognition and funding, is the crux of much of today's debate. Farmelo gives a lively description of the back-and-forth of contributions typical of any thriving interdisciplinary area, with physical problems stimulating mathematical breakthroughs and mathematics throwing up new insights and techniques in physics. He steers clear of discussing the infeasibly large 'string landscape' of possible physical theories to which the mathematical approach seems to have led — contrary to hopes of a unique 'theory of everything'. Instead, he concentrates on developments more directly useful and testable in physics, where some of this mathematical sophistication begins to feed back into an understanding of the standard model.

The standard model is a complex, subtle and immensely successful theoretical structure that leaves significant questions unanswered. Farmelo makes a convincing case that, in attempting to answer those questions, mathematics has a crucial role. Yet whether theoretical physics has become too enamoured of beautiful mathematics will, I suspect, remain a topic of hot debate.

The long experimental search for the Higgs was motivated by the fact that, before we accepted the existence of a quantum energy field that fills the whole Universe — part of the theory that predicted the particle — we demanded more evidence than 'it makes the maths come out right'. The need for evidence is even stronger if the argument is 'it makes the maths look beautiful'. The Universe might speak in numbers, but it uses empirical data to do so. ■

Jon Butterworth is professor of physics in the Department of Physics and Astronomy, University College London, and the author of *Smashing Physics* and *A Map of the Invisible*. He blogs at lifeandphysics.com
e-mail: j.butterworth@ucl.ac.uk

HISTORY

England's Galileo

Georgina Ferry relishes a biography of the formidable Moon-mapping Tudor scientist Thomas Harriot.

The phrase 'publish or perish' came into use in the twentieth century to encapsulate academic pressures. It is also a lesson from the life of Thomas Harriot, who lived when there were no academic journals, and who never taught at a university.

A contemporary of William Shakespeare, Harriot was an English mathematician, astronomer and natural philosopher whose original work bears comparison with that of Johannes Kepler and Galileo Galilei. Yet, outside the enthusiastic circle of historians of early modern science who call themselves Harrioteers, his name is almost unknown: he never published his mathematical work. In *Thomas Harriot: A Life in Science*, mathematician Robyn Arianrhod sets out to explain how historians have nevertheless been able to place him, almost four centuries after his death in 1621, among the founders of modern science.

Harriot is elusive. The earliest known document concerning him lists him as a "plebeian" scholar registering to study at the University of Oxford in 1577. He never married and left no children. By 1583, he was employed by Walter Raleigh, naval commander, explorer and favourite of Queen Elizabeth I, to teach astronomy and navigation — a field he greatly improved — to sea captains. He was celebrated in his lifetime by the writer Gabriel Harvey as among the "profound mathematicians", alongside Thomas Digges and John Dee. Afterwards, he was largely forgotten.

He has a higher profile in the United States, thanks to the one work he did publish. *A Brief and True Report of the New Found Land of Virginia* is a first-person account of a 1585–86 voyage sent by Raleigh to survey what is now part of North Carolina. The party landed on Roanoke Island and surveyed it and the nearby mainland; almost all its members returned to England in June 1586. Harriot was "employed in discovering". His report, published in 1588, includes the first detailed English description of the language and customs

Thomas Harriot: A Life in Science
ROBYN ARIANRHOD
Oxford University Press
(2019)

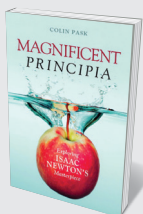
of the Algonquian people, and of the region's natural resources and climate. Arianrhod shows that his interest

in local people was far from typical: he learnt their language, admired how they interplanted beans, squashes and maize (corn), and respected their religion. Meanwhile, the military expedition leaders fatally soured relations by overreacting to perceived wrongdoing and making unreasonable demands.

Previous biographers — the US authors Henry Stevens in 1900 and John Shirley in 1983 — were prompted by the *Brief and True Report*. Neither fully addressed Harriot's scientific contributions, as Arianrhod tries to do. Harriot's will mentioned a trunk full of mathematical papers. A few were circulated and partly published by friends such as the mathematician Walter Warner after his death, but what became of the collection was unknown until 1784, when it turned up in some disorder at Petworth House, home to heirs of the ninth Earl of Northumberland, Harriot's patron after Raleigh. Only since the mid-twentieth century have scholars made sense of the thousands of manuscript sheets.

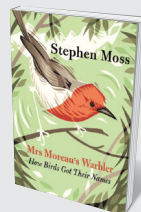
What they reveal is astonishing. To mention only a portion of Harriot's work, he discovered Snell's law of refraction two decades before mathematician Willebrord Snell; formulated laws of motion and falling bodies independently of Galileo and decades before Isaac Newton; produced the first drawing of the Moon through a telescope and made important observations of sunspots, again independently of Galileo; played with binary arithmetic nearly a century before Gottfried Wilhelm Leibniz; and was the first to develop fully symbolic algebra. There are well-grounded suspicions that René Descartes saw some of Harriot's papers before publishing *The Geometry* in 1637.

Where Harriot falls down, say some ▶



Magnificent Principia

Colin Pask PROMETHEUS (2019)
Isaac Newton remains a giant of physics, as his 1687 *Principia* confirms. Maths historian Colin Pask presents an easily digestible guide to the work, enlivened with passages from Newton's life. An invitation to wonder at what some see as the greatest single scientific book ever published.



Mrs Moreau's Warbler

Stephen Moss FABER (2019)
Names make sense of the world; they also reveal something about us. Stephen Moss unveils the often surprising roots of avian etymology and offers insight into fierce, long-standing debates such as that over *Prunella modularis*, variously known as the dunnock and hedge sparrow.

► scholars, is that he did not draw his observations into coherent theory. It's possible he just never got round to it. Harriot spent his adult life in the households of Raleigh and Northumberland. They paid him generously, and all appearances suggest that he was a friend rather than a servant. However, both were players on the volatile political scene, and malicious rumours of atheism and necromancy did the rounds. Soon after James I succeeded Elizabeth I in 1603, Raleigh was convicted of treason, and Northumberland of lesser charges when a cousin was involved in the Gunpowder Plot to murder the king. Both were imprisoned in the Tower of London; Raleigh was executed in 1618.

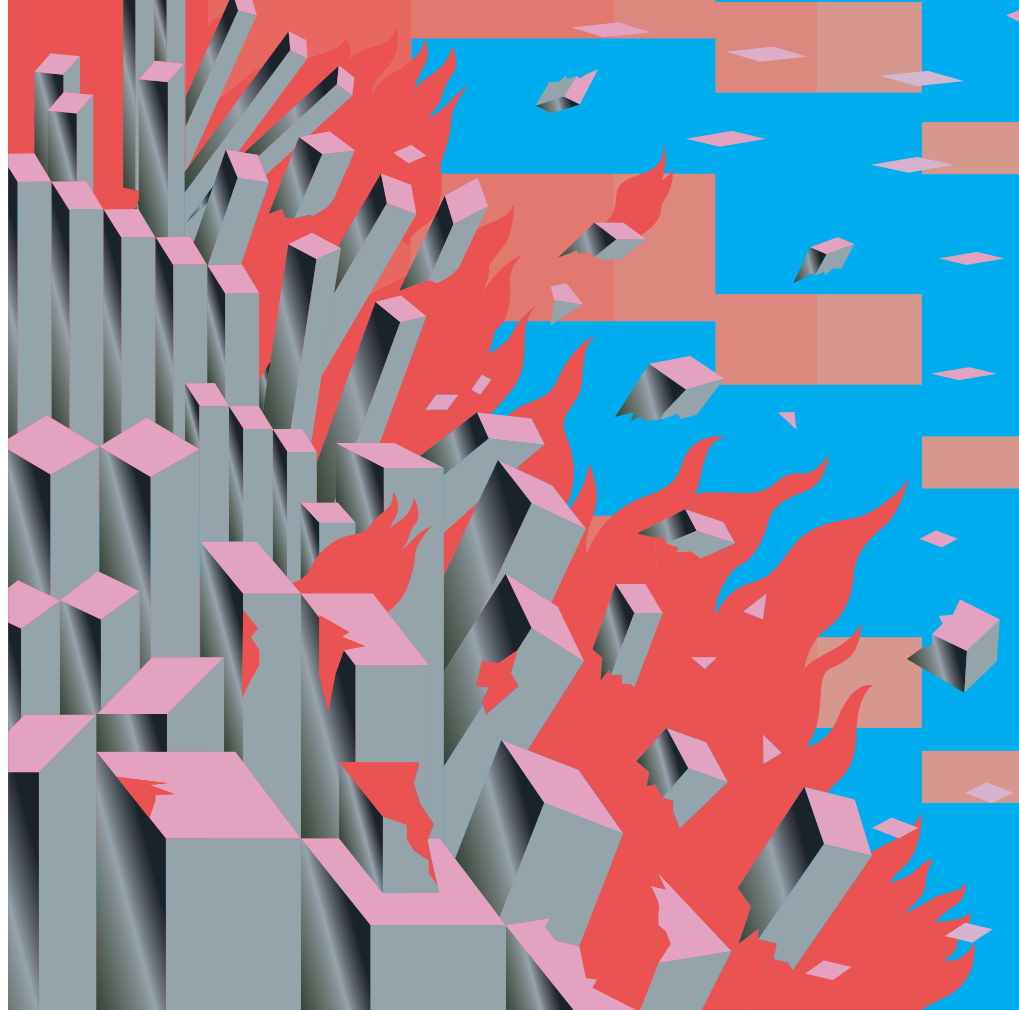
Harriot spent an anxious few weeks in prison because of his association with Northumberland; he might have felt the need to keep his head down over the years. He died aged about 60 from cancer of the nose, possibly caused by his enthusiasm for tobacco after his American adventure.

The lack of finished work makes evaluating his contribution complex. Arianrhod does not hesitate to call him a genius, and the evidence she presents is impressive. Yet she fully explores his rightful position in the pantheon only in a page-long endnote; I think this short-changes the “general reader” she seeks to enlighten. Some might find her technical passages challenging, although they are necessary to her argument. And it is irksome to see diagrams relating to Harriot's navigational work in an appendix, rather than with the text they illustrate.

Has Arianrhod, as she intended, “put a human face to scientific inquiry in the Elizabethan and Jacobean worlds”? She has revealed a scientific mind, but the face is more elusive: the one supposed portrait of Harriot is of unknown provenance and, because of a discrepancy in dates, some historians doubt it is him.

This black-clad, driven, sceptical man, “contented with a private life for the love of learning” as he wrote to his captors, still declines wholly to step into the light. ■

Georgina Ferry's biography of Dorothy Crowfoot Hodgkin will be published in a revised edition this year.
e-mail: georgina.ferry@gmail.com



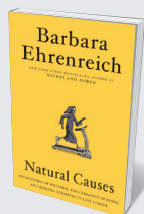
SOCIETY

How to survive an apocalypse

Richard Rhodes weighs up Jared Diamond's study of national resilience in the face of catastrophe.

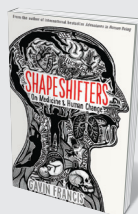
The geographer Jared Diamond is the bestselling author of a number of books on the vicissitudes of civilizations. His anchoring perspective, argued across such works as *Collapse* (2005) and *The World Until Yesterday* (2012), is geographic determinism. He sees the environment as fundamentally shaping the founding,

development and challenges of nations and civilizations. “History,” he argued in the 1997 *Guns, Germs, and Steel*, “followed different courses for different peoples because of differences among peoples’ environments, not because of biological differences among peoples themselves.” His perspective has been both celebrated for clarifying historical



Natural Causes

Barbara Ehrenreich GRANTA (2019)
Our bodies, notes writer Barbara Ehrenreich, are a cellular battleground, where our immune systems can aid the growth of tumours. Attacking the rose-tinted ‘wellness industry’ and advocating a realistic view of death, she will change how you view your own mortality.



Shapeshifters

Gavin Francis WELLCOME COLLECTION (2019)
“To be alive is to be in perpetual metamorphosis.” Physician Gavin Francis tackles bodily transformations that can aid or constrain us — from pregnancy to amputations. With real insight, he intertwines case studies with his amazement at how our bodies surprise us.