With such caveats, Townsend conveys a cautious optimism that information technology might make cities smarter. But the book only nibbles at the edges of fundamental shifts in how data-driven cities might operate in future. Top-down versus bottom-up approaches to urban development are discussed anecdotally, neglecting a deeper analysis of cities that exemplify an organic "organized complexity", as social critic Jane Jacobs described decades ago.

Perhaps the history of failed top-down urban planning models has left Townsend sceptical of systematic and quantitative scientific analyses of cities. However, we need a scientific understanding of what makes cities adaptive, resilient and prosperous, as we create ever more, and ever larger, urban environments.

In *The New Science of Cities* (MIT Press, 2013), urban planner Michael Batty proposes a new approach based on models grounded in volumes of data that reveal fine details of how individuals behave in urban environments. Equally important is a growing understanding of cities as dynamic systems driven by top-down and bottom-up processes. The macroscopic analysis of cities led by Luis Bettencourt and Geoffrey West at the Santa Fe Institute in New Mexico reveals regularities in how cities are distributed and grow, and common patterns in how transportation, the pace of innovation and economic activity vary across cities of different sizes. This work, and my own, suggests that urban energy and information flow are governed by basic physical principles, even given cities' different histories, politics and cultures. To understand cities, we need not just the abundant data that sensored cities will produce, but also a new framework to understand how individual stories are woven into vibrant urban systems.

***"Cities will need to be smarter than the sum of their parts."***

On a rapidly urbanizing planet, smart cities will dominate the human cultural landscape and affect how we live, consume resources and manage the environment. Cities will need to be smarter than the sum of their parts and founded on more than routers, protocols and social networking apps. Townsend begins a conversation, but we owe it to ourselves to develop a quantitative, integrated science of cities to guide our vision of how we will grow, govern, live and work in tomorrow's smart cities.

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QUANTUM PHYSICS

# Packet man

**Graham Farmelo** delights in a study of Albert Einstein's under-appreciated contributions to quantum theory.

**Einstein and the Quantum: The Quest of the Valiant Swabian**
A. DOUGLAS STONE
*Princeton University Press: 2013.*

In 1941, US physicist John Wheeler visited Albert Einstein, the arch quantum sceptic, at his home in Princeton, New Jersey. Wheeler was hoping that the beauty of the new version of quantum theory developed by his brilliant student Richard Feynman would persuade Einstein to accept that the theory was simply a natural development of well-founded classical ideas. The sage of Princeton listened in silence as Wheeler set out his case, but afterwards was no more enthusiastic. "Of course, I may be wrong," he said, "but perhaps I have earned the right to make my mistakes."

Einstein was by that time a semi-detached member of the physics community, admired much less for his current work than for his achievements. Many of his colleagues thought his views on quantum theory cranky — Robert Oppenheimer dismissed them as "cuckoo". That opinion is sometimes echoed today in popular books, many of which underestimate his contributions to the theory.

In *Einstein and the Quantum*, Douglas Stone attempts to put that right. He describes Einstein's work on the theory using few equations, combining scientific and biographical accuracy with wide accessibility. Stone, a distinguished condensed-matter physicist at Yale University in New Haven, Connecticut, brings a wealth of physical insight and — less predictably — an impressive familiarity with the work of leading Einstein scholars.

In 1900, Max Planck introduced the revolutionary idea of energy quantization in the interaction between matter and radiation in black bodies. But, as Stone explains, it was Einstein who first understood the implications. In 1905, the 26-year-old physics wizard radically suggested that the energy of electromagnetic radiation is transferred in the discrete amounts that Planck called quanta. For physicists of the day, long familiar with James Clerk Maxwell's wave description of light, Einstein's notion was beyond heretical. Few leading theoreticians took it seriously, least of all Planck.

Even Einstein wavered. He strove for years to understand radiation quanta, for example by tinkering with Maxwell's equations of electromagnetism. Eventually he abandoned this approach, having introduced the useful but murky concept of wave–particle duality.

**Albert Einstein at his home in Berlin.**

UNDERWOOD & UNDERWOOD/CORBIS

Yet, more than any other scientist, Einstein ran with the quantum idea. Applying it to the vibrational energies of atoms, he used it to predict that the specific heats of solids should vanish as the temperature is lowered towards absolute zero. Quoting an early statement of Einstein's about atomic energy, Stone adds with characteristic pith that energy quantization "is not a mathematical trick; it is the way of the atomic world. Get used to it."

Each of the 29 chapters in *Einstein and the*

*Quantum* is brief, pacey and lucid (although some titles are perhaps too clever: for example, 'Stalking the Planck'). The breadth and depth of Einstein's contribution in this area becomes overwhelmingly clear. Eleven years after his first great paper on the subject, he delivered a theory of transitions that introduced into quantum theory the idea of probabilities, which he came to despise. Finally, in 1924, he built on the thinking of Indian physicist Satyendra Bose about quantum gases and predicted that, under some conditions, a high proportion of particles could occupy the lowest quantum state, enabling quantum effects to appear in the everyday world. This was later called Bose–Einstein condensation and was first observed experimentally in 1995.

Stone covers all this with clarity and even tackles Einstein's little-known 1917 paper on the quantization of chaotic systems. This chapter will probably leave non-specialists scratching their heads, but it is worth a read because it demonstrates that there is more to Einstein's *oeuvre* than even most quantum physicists know. Stone concludes that Einstein's work was worthy of four Nobel prizes, and it is a measure of the book's achievement that his claim sounds quite reasonable.

It was left to Werner Heisenberg, Erwin Schrödinger and Paul Dirac to set out the full-blown quantum theory of matter in the mid-1920s. Einstein was a formidable critic of the theory, although he was always outwitted in argument by his friend Niels Bohr — a topic treated only briefly in the book, probably because this ground is so well-trodden. Yet all the originators were indebted to Einstein's thinking. As Max Born later said, he was "clearly involved in the foundation of wave mechanics and no alibi can disprove it".

In old age, Einstein seemed indifferent to his reputation as a fuddy-duddy, but the criticisms may have hurt more than he let on. I have often wondered how he felt when he saw the Princeton University Players' production of William Shakespeare's *The Tempest* in July 1953, especially when Prospero contemplates the fleeting nature of existence that leaves "not a rack behind". Einstein died less than two years later. He was proud to have built the great edifice of relativity, but still profoundly dissatisfied with quantum theory, which he was confident would be superseded.

Was he wrong? Some theoretical physicists are now speculating that space and time might in some sense emerge from the more fundamental quantum, so it may be that scientists will one day regard Einstein's greatest achievement as pioneering a theory he believed was terribly flawed. In the meantime, Stone's rewarding book helps us to appreciate the remarkable extent of that feat. ■

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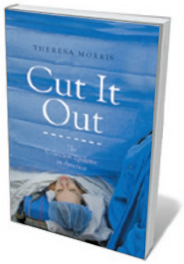
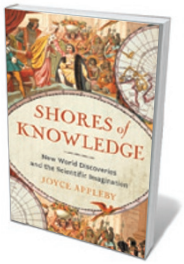
# Books in brief


**Junkyard Planet: Travels in the Billion-Dollar Trash Trade**
*Adam Minter* BLOOMSBURY *(2013)*
Junk really is filthy lucre — the basis of a global scrap trade worth up to US$500 billion a year, writes Adam Minter. Scion of a professional recycling family, Minter anatomizes this complicated, half-hidden industry that he argues is, even at its dirtiest, greener than harvesting raw resources. He focuses on scrap metal, a prized commodity now recycled in innovative ways, and the kingpins of the trade. Leonard Fritz, for instance, rose from extreme poverty to run the Michigan-based Huron Valley Steel Corporation, which annually processes almost half a million tonnes of shredded automobile.




**Cut It Out: The C-Section Epidemic in America**
*Theresa Morris* NEW YORK UNIVERSITY PRESS *(2013)*
Birth by Caesarean section is expensive and carries a higher risk of medical complications than vaginal birth. Yet in 2011, 33% of US births were by Caesarean. To investigate why, sociologist Theresa Morris crunched the numbers and interviewed more than 100 medical staff and mothers. The culprit, she concludes in this excellent and detailed study, is a risk-averse US medical culture that favours heavily managed births — such as the overzealous use of fetal heart monitors, which restrict the mother's movement — and that frowns on women having vaginal births after Caesareans.




**Shores of Knowledge: New World Discoveries and the Scientific Imagination**
*Joyce Appleby* W. W. NORTON *(2013)*
A sea change gripped Europe from the late 1400s as word of the thrillingly strange New World spread. Maps were redrawn and the 'book of nature' swelled with new species, from penguins to chillies. In a history stretching from Christopher Columbus to Charles Darwin, Joyce Appleby reveals how a thirst for empiricism grew with the need to sift out tall tales from genuine reportage. She treads the trail of paper and specimens left by the likes of ethnographer Bernardino de Sahagún and "first ecologist" Alexander von Humboldt.


**To the Letter: A Journey Through a Vanishing World**
*Simon Garfield* CANONGATE *(2013)*
The letter — that pillar of the historical record — may itself soon be history. As Simon Garfield reminds us in this elegy to the post, letters uniquely revivify past eras and the psychological complexities of people living through them. The first stirrings and exponential rise of e-mail are touched on, but Garfield's focus is the physical missive and the depth of thought it allows. From wooden tablets dug up at the ancient Roman garrison Vindolanda, UK, to the epistolary gems of novelist Virginia Woolf, this is a billet-doux to two millennia of the impassioned, often life-changing power of private correspondence.


**Survive! Inside the Human Body, Vol. 1: The Digestive System**
*Gomdori co., Suk-young Song and Hyun-dong Han* NO STARCH PRESS *(2013)*
From volcanic burps to colonic bacteria, this comic-book ride through the human digestive system is a delirious joy for pretty much everyone aged eight and over. Hyun-dong Han's lurid images and zippy text by Suk-young Song deliver on facts even as they shamelessly milk the 'yuck' factor. Take the plunge with hero Geo and "self-proclaimed genius" Dr. Brain as they shrink and are sucked into the ever-hungry Phoebe: the ultimate inside story. **Barbara Kiser**