

## Books & arts

The heart of Halpern's book is the conflict between human intuitions of deep connections in the Universe, and the scientific case for such links. He sweeps the reader from the early Greeks to modern physics – from the works of Plato and Empedocles, Johannes Kepler, Galileo Galilei, Isaac Newton, James Clerk Maxwell and others, to the arrival of relativity and quantum mechanics – building a case for potential connections without causality. A coda deals with the most recent experiments on entanglement, involving satellites, and nods to complex theoretical work that connects entanglement to the nature of space-time.

It an often-told tale, but Halpern strives to keep it fresh. For example, the conundrum of black-body radiation was solved by German physicist Max Planck's hypothesis in 1900 that energy must come in quanta – minimum units that cannot be divided further. Halpern explains this evocatively, in terms of a jet-black mug of tea with a lid, heated in a microwave oven to 100°C. Pre-quantum theories predicted, implausibly, that this would be a source of hazardous, high-frequency ionizing radiation. Planck showed that quantization limits or even eliminates the energy emitted at high frequencies. His ideas kick-started quantum mechanics, and explain why we can sip hot tea without getting radiation burns. Despite such anecdotes, parts of the book could be hard going for those unfamiliar with the concepts.

### Conservation laws

One key to understanding acausal connections, often given short shrift, is the work of German mathematician Amalie 'Emmy' Noether, an important figure in *Synchronicity*. In the early twentieth century, she showed that symmetries in nature and the laws of conservation are two sides of one coin. For example, a spinning bicycle wheel has rotational symmetry: turning on its axis does not change the wheel. Conservation of angular momentum follows from rotational symmetry. Conservation laws, in turn, affect long-range, acausal phenomena. The angular momentum of two particles emitted from the same interaction has to be conserved, even if the particles end up kilometres apart. This leads to correlations in their measured properties.

More than the physics, it's the scuttlebutt about the personalities that makes the book shine. It's shocking to read how Pauli and German mathematician Pascual Jordan (an early contributor to quantum mechanics) were interested in parapsychology. Jordan was taken with experiments by the US botanist Joseph Banks Rhine – ostensibly showing that some people could read minds, guessing the images on hidden cards at a rate better than chance. Pauli "was open to speculation about numerology and the supernatural, an interest cemented through his interactions with Carl Gustav Jung", writes Halpern. It's a reminder

that even extraordinarily rational intellect can come up short when confronted with the subjective depths of one's own being.

It's also shocking to see the unglamorous sides of Pauli and German theorist Werner Heisenberg. The charm and energy of youth behind them – along with their Nobel prizes – they struggled to remain relevant. Late in their careers, the duo developed the idea of a single field "from which all matter, energy, and natural interactions would coalesce as special cases". When Pauli presented their ill-formed theory at a 1958 conference of the American Physical Society, he was met with derision.

To his alarm, Heisenberg began publicizing the work in Germany. Pauli wrote to a student about "Heisenberg's radio- and newspaper-advertisement, with him in the principal role of super-Einstein, super-Faust, and super-human?"

His passion for publicity seems insatiable." Albert Einstein spent his final years trying to reconcile relativity with quantum mechanics, but even his dogmatism was imbued with grace.

Connections between seemingly disparate elements and characters coalesce and connect in the book's second half, a pleasing echo of the story. For example, Heisenberg and Pauli's attempts recall Plato's idea of a timeless realm of perfect forms underlying our observed reality. Rightly or wrongly, with much to uncover about how the Universe works, the allure of acausal connections remains.

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Ethan Hawke plays electricity pioneer Nikola Tesla.

## Tesla biopic, starring Ethan Hawke: eccentric portrayal

The inventor of alternating current, motors and more is back – and this time, he sings. **By Davide Castelvecchi**

**T**he mystique surrounding the Serbian American inventor Nikola Tesla (1856–1943) is rather baffling. In life, far from being underrated or forgotten, Tesla was a celebrity. He rose from humble Balkan beginnings in a village in what is now Croatia to cavort with New York high society.

The most successful of his inventions – the alternating-current (AC) induction motor and generator – helped US entrepreneur George Westinghouse and his AC power-transmission system to win the electricity war against inventor Thomas Edison and his direct-current version.

In death, Tesla's cult status has only grown. The SI unit of magnetic-field strength is named after him. Two electric-car companies bear his first and last name. The Tesla flame has been kept alight by biographies, documentaries, movies (one with actor and filmmaker Orson Welles, another with musician David Bowie) and even an opera. Fans, it seems, are drawn as much by his inventiveness as by his wilder ideas – such as using Earth and its atmosphere to wirelessly conduct electricity around the globe.

His is a story of an eccentric genius that each age retells in its own image. The latest biopic *Tesla*, directed by Michael Almereyda, is released this week.

The film exploits jarring gimmicks. In an early scene, Tesla (played by Ethan Hawke) and Edison (Kyle MacLachlan), splatter ice cream on each other's suits during a heated argument. The frame freezes, and Tesla's friend Anne Morgan (Eve Hewson), the daughter of fabled financier J. P. Morgan, tells us that this fight never happened. Becoming the on-screen narrator, Morgan breaks the fourth wall to say that googling 'Nikola Tesla' gets 34 million search results – evidence, she assures us, that Tesla is famous, although not quite as famous as his arch-enemy Edison, who has 64 million results. "Twice as many as Tesla," she adds, glancing at the camera.

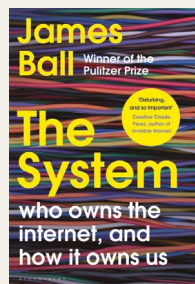
Thumping dance music underscores a party thrown by French actress Sarah Bernhardt (Rebecca Dayan). Edison consults a smartphone while the narrator speculates on what the rivals could have achieved together. Painted backdrops depict scenes such as the Colorado setting of Tesla's experiments with artificial lightning and wireless transmission. The cherry on top of this misbegotten cake is Hawke's rendition, in faux-Slavic accent, of the song 'Everybody Wants To Rule the World' by the 1980s band Tears for Fears.

Perhaps Almereyda's point is that Tesla was the Steve Jobs of his time – a testy, workaholic visionary and showman who disrupted his age with beautiful ideas that caught Wall Street's eye. But it is an unconvincing comparison: unlike Jobs, Tesla had no innovation factory to realize his wizardry at scale.

The film skirts some more interesting and less-explored aspects of his personal relationships, described in the 2013 biography *Tesla* by historian Bernard Carlson. For instance, Tesla was capable of pettiness in intellectual-property disputes – including those he had won, as in the case of the induction motor. Some have speculated that Tesla and Edison might both have missed out on a Nobel prize because the committee was turned off by their squabbles. Perhaps an ice-cream fight would have been the least of it.

**Davide Castelvecchi** is a senior reporter for *Nature* in London.

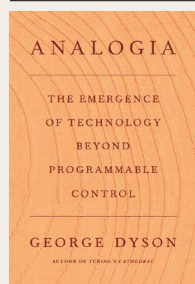
## Books in brief



### The System

James Ball *Bloomsbury* (2020)

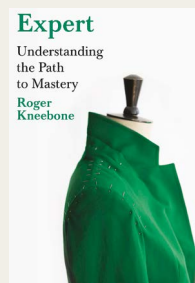
Journalist James Ball was part of the award-winning team that covered US National Security Agency online surveillance for newspaper *The Guardian*. His incisive insider study on who owns the Internet draws on programmers, executives, whistle-blowers and academics to describe how the Internet's leading companies – Amazon, Apple, Facebook and Google – are "engines running along the railway lines set out by the internet's very structure". He argues that, like railways, the Internet must become subject to competition law for the good of society.



### Analogia

George Dyson *Farrar, Straus and Giroux* (2020)

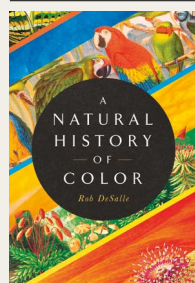
Philosopher Bertrand Russell supposedly asked: is the world a bucket of molasses or of sand? In other words, is nature analogue or digital – or both? This problem fascinates historian of technology George Dyson. His engaging, if digressive, meditation ponders how nature's coding is digital for intergenerational instructions in DNA, but analogue, in brains and nervous systems, for real-time operations. "The next revolution", he predicts, "will be the coalescence of programmable machines into systems beyond programmable control."



### Expert

Roger Kneebone *Viking* (2020)

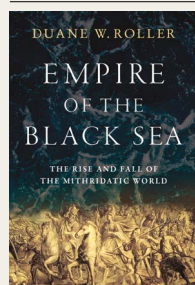
"The greater the expertise, the less you notice it," writes Roger Kneebone in his vividly practical analysis. Once a consultant surgeon, then a family doctor, he is now a university researcher investigating what experts in diverse fields can learn from one another. He cites a riverbank walk with an angler friend, silently spotting a swarm of invisible fish from surface ripples, shadows, the sun's glint and flies' patterns. He worries that scientific expertise will diminish because student teaching is now too dependent on watching scientists online.



### A Natural History of Color

Rob DeSalle and Hans Bacher *Pegasus* (2020)

Mantis shrimp eyes probably contain 16 visual pigments, compared with 3 for humans. These allow the shrimp to communicate using dazzling reflected displays of polarized and other light. By contrast, avant-garde artist Neil Harbisson, born without colour vision, has an antenna implanted in his skull to let him 'hear' colours, even beyond the human visual spectrum. Biologist Rob DeSalle and physicist Hans Bacher illuminate many such fascinating facts in their study of colour, accompanying an American Museum of Natural History exhibition.



### Empire of the Black Sea

Duane W. Roller *Oxford Univ. Press* (2020)

Mithridates VI, last king of Pontus, ruled most of the Black Sea coast, clashed with the Roman empire and was defeated in 66 BC. Roman statesman Cicero called him "the greatest king since Alexander". Classicist Duane Roller agrees, and notes that the famously polyglot Mithridates intensified his lifelong study of poison and antidotes before his suicide in 63 BC. But Roller resurrects much more than a single king in his pioneering history, the first ever English-language analysis of the entire Mithridates dynasty. **By Andrew Robinson**