unintelligible, observations had to catch up. From mid-century, astronomers looked at the Universe in electromagnetic wavelengths from radio waves to γ-rays, and identified distant objects that generated geysers of radiation — a match for theoretical black holes. Theorists such as Stephen Hawking tried to divine what happens at the event horizon — the boundary between this Universe and whatever lies beyond the gravitational field.

Further advances, such as the Hubble Space Telescope, made the evidence overwhelming. Supermassive black holes probably occupy the centre of every galaxy and determine galactic growth. Over about 50 years, black-hole studies have gone from obscurity to a thriving industry. Theorists, Impey writes, are "in a golden age", and observers "are harvesting massive black holes on an industrial scale".

The harvest of two black holes is the subject of Fletcher's book. One lies in the relatively nearby Virgo A galaxy. The other, the supermassive candidate Sagittarius A*, is at our Galaxy's heart. Observations of black holes have generally relied on indirect evidence, given the constraints of attempting to 'see' a black object on a black background at distances of up to several billion parsecs. The evidence for Sagittarius A* includes numerous studies over the past 20 years, revealing the zigging and zagging of nearby stars and gas under its apparent influence. But the Event Horizon Telescope (EHT) has tried to observe it directly.

Fletcher, chief features editor at *Scientific American* (which shares a publisher with *Nature*), tells this story. To bring such an observation into the realm of the possible, a telescope would need an aperture the diameter of Earth. By using very-long-baseline interferometry — combining observations from multiple, far-flung radio telescopes — the EHT team conceived an apparatus effectively covering the Western Hemisphere. For one week in April 2017, that network focused on the centre of the Milky Way to extract images such as the blazing radiation that should be generated by matter heating up to billions of degrees as it orbits the black hole at velocities approaching the speed of light.

Fletcher secured close access to the EHT collaboration, particularly director Sheperd Doeleman. Its results aren't public yet, leaving a hole at the heart of Fletcher's narrative. He compensates with a compelling behind-the-scenes story of scientists struggling as much with funding and competition as with the challenges of seeing Sagittarius A*.

Both books address the seeming absurdities of their subject with authority and wit. Fletcher characterizes the EHT as a "distributed Babel, constructed on as many as a dozen high perches". And after describing a death spiral between two black holes, each 10 million times the mass of Earth and hurtling around each other at half the speed of light, less than 200 kilometres apart, Impey concludes: "This isn't an orbit, it's insanity."

Maybe. But if history is any guide, it won't seem so for long. Improvements to gravitational-wave detectors such as the Laser Interferometer Gravitational-Wave Observatory should make the detection of black-hole collisions routine, inspiring a new generation of theorists to address the incompatibility of general relativity and quantum mechanics. As these two books make clear, the study of black holes has progressed rapidly from "No way!" to "Oh, wow." The next step is: "What now?" ■

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NEUROIMAGING

The brain decoders

Chris Baker enjoys a clear-eyed account of the promise and pitfalls of brain imaging.

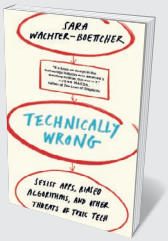
Since the advent of neuroimaging in the 1980s with positron emission tomography (PET), the sight of a living human brain in action has captivated scientists and the public. The emergence of functional magnetic resonance imaging (fMRI) in the early 1990s was a watershed. MRI scanners were already common in hospitals and, unlike PET, fMRI does not expose people to radioactivity. By measuring activity in the brain at the scale of a few millimetres, these scans seem to promise profound insight into the workings of the brain. That has led to wild claims that the technique could enable mind reading — actually knowing a person's precise thoughts.

The New Mind Readers: What Neuroimaging Can and Cannot Reveal about Our Thoughts
RUSSELL A. POLDRACK
Princeton University Press (2018)

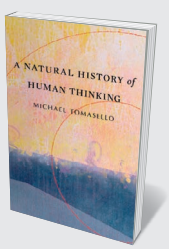
Russell Poldrack tackles these claims head on in *The New Mind Readers*. The experimental psychologist and neuroimaging pioneer takes readers through three decades of fMRI, its promise and limitations. From the race between groups in Minnesota, Massachusetts and Wisconsin in 1991 to show that MRI measures of blood oxygenation can reflect functional brain activity, to the development of techniques for decoding what someone is looking at, Poldrack surveys the history and biological basis of the technique and its potential application in areas as diverse as law and psychiatry.

Poldrack is an ideal guide. As director of the Stanford Center for Reproducible Neuroscience in California, he actively advances fMRI methods. His enthusiasm for them is clear, as is his frustration at how their data have been misinterpreted and abused.

The technique has revolutionized neuroscience. Thousands of fMRI studies are published each year on topics ranging from perception to decision-making. For example, we now know that the pattern of blood flow



Technically Wrong
Sara Wachter-Boettcher W. W. NORTON *(2018)*
Technology permeates life, from grocery shopping to dating apps. Yet we rarely question its design or aims. Web consultant Sara Wachter-Boettcher proffers a damning critique of the ethical dilemmas it poses, and why we need to demand more accountability from tech creators.



A Natural History of Human Thinking
Michael Tomasello HARVARD UNIV. PRESS *(2018)*
Drawing on 20 years of comparative studies on humans and great apes, psychologist Michael Tomasello theorizes that human cognition arose from social cooperation. Language and culture, he posits, also grew from our ancestors' need to work collaboratively.

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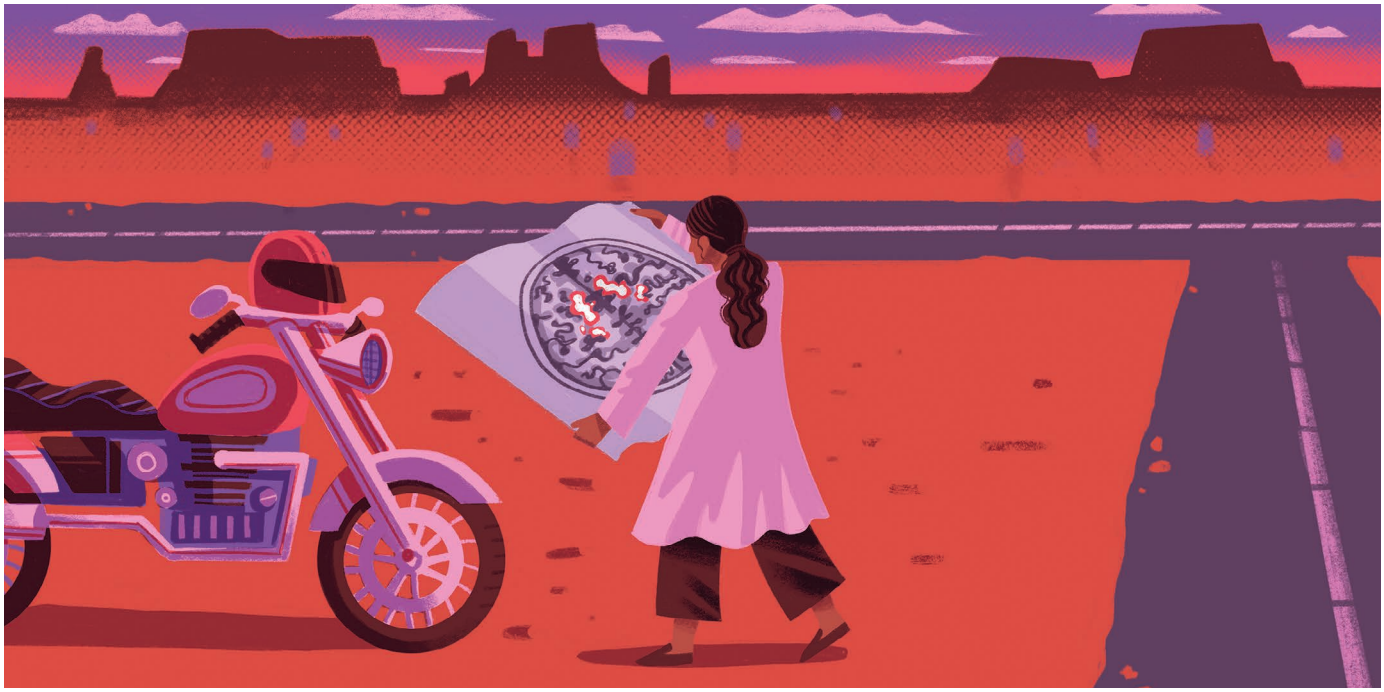


to the fusiform face area in the temporal lobe can indicate that a person is looking at a face instead of a ball; and that imagining playing tennis or walking around your house, say, elicits activations in different brain regions. That is a major advance for neuroscientists and physicians who work with people in apparently non-responsive states after brain injury. It means they can identify patients with conscious awareness simply by asking them to engage their imaginations.

But some claims for fMRI are exaggerated. In 2007, *The New York Times* published an article based on fMRI data collected while people viewed images of candidates in US presidential primary elections, such as Barack Obama and John McCain. A group of neuroscientists at the University of California, Los Angeles, and political scientists had interpreted the results, alleging that they revealed how swing voters felt about the candidates.

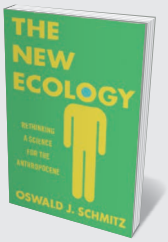
As Poldrack explains, the trouble is that activations of particular brain regions — such as the amygdala and the insula, which have been associated with fear and disgust, respectively — are not uniquely associated with particular mental states. One region, the anterior cingulate cortex, was found to be active in about one-quarter of thousands of studies that Poldrack and his colleagues examined, including those involving pain, short-term memory and cognitive control. So, 'reverse inference' of thoughts from brain-activation patterns can be very misleading. The potential for outlandish claims is high, Poldrack shows, when scientific data are used to support political and commercial interests — for example, when companies promote the ability to detect lies or to evaluate how viewers respond to advertising without sufficient scientific rigour. *The New Mind Readers* is a valuable example of how science can be discussed clearly and even-handedly, without sensationalism.

THE POTENTIAL FOR OUTLANDISH CLAIMS IS HIGH.

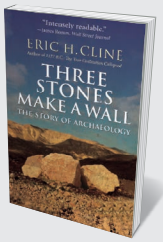
One of Poldrack's key themes is that interpreting fMRI findings demands an understanding of the underlying data and how they were produced. These scans do not measure neural activity directly. They rely on changes in the magnetic properties of haemoglobin (depending on levels of oxygen), to reveal local differences in blood flow. These reflect neural activity and are associated with different mental states, such as increases in the activity of motor cortex while tapping the fingers. When a technique involves hundreds of thousands of measurements across the brain, it is challenging to distinguish between a real change and a chance observation. Concerns over reproducibility are prominent. Moreover, many experiments use only a small sample, of fewer than 20 participants, often university students, in a laboratory setting.

Caution is needed about generalizing to more complex, real-world situations. These include driving a car down a busy motorway, or moving from average activation patterns to single brains in a much more diverse general population, ignoring the importance of the individual variability that is part of being human.

The New Mind Readers is personal and selective. Poldrack gives short shrift to some methods, including brain stimulation, in which magnetic pulses are used to alter brain function directly to probe the ▶



The New Ecology
Oswald J. Schmitz PRINCETON UNIV. PRESS *(2018)*
As we strive for sustainability amid unprecedented global transition, ecology is evolving to encompass the interdependence of human agency and nature. Ecologist Oswald Schmitz calls for careful stewardship and conservation of biodiversity to foster ecosystem resilience.



Three Stones Make A Wall
Eric H. Cline PRINCETON UNIV. PRESS *(2018)*
Archaeologist Eric Cline walks us through the fascinating history of his discipline, traversing civilizations and the globe. From the discovery of Tutankhamun's tomb in Egypt to the future of excavation as technology advances, this is an engaging introduction to a gripping field.

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specific role of the region targeted. He also skimps on neuroimaging techniques such as magnetoencephalography, which directly measures changes in magnetic fields produced by electrical signals in the brain. This is not an exhaustive account, and Poldrack focuses only on key developments and pioneers close to his own work. Yet his idiosyncratic approach is deeply engaging.

I was fascinated by Poldrack's description of why he decided to scan himself more than 100 times over 18 months to investigate how the brain changes over time — despite enduring a panic attack the first time he went into an MRI scanner. This intensive study uncovered much about the stability of brain function and the factors that affect it (including caffeine, food and mood). Yet Poldrack reveals that he learned "depressingly little" about himself during the experiment, highlighting the challenges of using fMRI for personalized medicine.

At times, Poldrack loses focus. His brief forays into topics such as the nature of mental illness are unsatisfying: they are too brief and lack the clarity of the rest of the book. Nevertheless, this is a compelling introduction that lucidly spells out the risks of taking media reports at face value, and urges readers to dig into the details. fMRI is evolving rapidly and researchers are just starting to map brain activity at sub-millimetre resolution, revealing activity — both in different regions and in different layers of cortex within a region.

Happily, despite the book's title, Poldrack makes it clear throughout that 'mind reading' as most people would imagine it remains in the realm of science fiction. What is much more exciting is the potential of fMRI for providing insight into brain function that will ultimately lead to clinical applications. ■

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The views expressed do not necessarily represent those of the US National Institutes of Health, the Department of Health and Human Services or the US Government.

ATOMIC PHYSICS

Secret histories of the bomb

Sarah Robey examines two books that together trace the birth and evolution of the nuclear age.

Fallout: Conspiracy, Cover-Up, and the Deceitful Case for the Atom Bomb
PETER WATSON
PublicAffairs (2018)

Burning the Sky: Operation Argus and the Untold Story of the Cold War Nuclear Tests in Outer Space
MARK WOLVERTON
Overlook (2018)

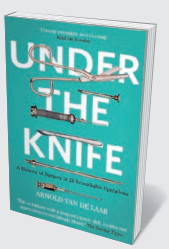
The secretive twentieth-century history of nuclear weapons is an evergreen subject. Writers have mined it for stories of breakneck innovation, wrenching controversy, unimaginable violence, espionage and larger-than-life personalities. Two new books — *Fallout* from historian Peter Watson and *Burning the Sky* by science writer Mark Wolverton — continue this trend, recalling two instructive episodes in our collective nuclear past.

Fallout synthesizes the history of the race to create an atomic bomb in Germany, the United Kingdom and the United States from the 1930s to the end of the Second World War — a story of duplicitous players, sinister decisions and regrettable outcomes. In a twist of historical fate, Adolf Hitler's rise coincided with major breakthroughs in particle physics, including the theorization of nuclear fission by Lise Meitner and Otto Frisch in December 1938. By the time war broke out, many prominent scientists had fled the Reich, and the Allies assumed that any physicists remaining in Germany, including Werner Heisenberg, were working to harness fission to produce a bomb (see A. Finkbeiner *Nature* **503**, 466–467; 2013). This was the main reason that Britain and the United States sought to beat Hitler to the punch.

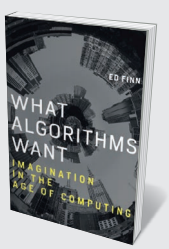
But, as Watson uncovers, British intelligence showed that Germany's atomic programme had stalled by 1942. Why, then, did the joint UK–US atomic programme move forward, despite incredible cost and danger? Watson painstakingly outlines a complex web of who knew what, and when, to show how a series of opportunities to stop what became the Manhattan Project arose, then passed. In 1942, without access to full British intelligence, the US government actually ramped up its project, assuming that Germany was advancing rapidly. As Watson puts it, "a series of momentous mistakes were made, and lies told" by French, German, British and US officials. Thus "the world stumbled, even blundered, unnecessarily into the nuclear age". In his view, today's extraordinary nuclear challenges — deteriorating arsenals, ongoing proliferation and the rebirth of sabre-rattling nuclear diplomacy — were preventable.

Watson's meticulous attention to this chronology is one of the book's strengths. He details wartime research on both sides of the Atlantic, from Copenhagen to New Mexico, and delves into the motivations and actions of the Allied leadership. Also interesting are his findings on the public availability of nuclear research in contemporary press reports and scientific journals, including *Nature*. Managing these threads is no small authorial feat — of research, especially. Watson also weaves together the insights of previous nuclear historians, such as Richard Rhodes, Martin Sherwin and David Holloway.

In what could have been a volume in its own right, the narrative is bookended by the overlapping wartime sagas of Niels Bohr and Klaus Fuchs. Fuchs, the infamous German



Under The Knife
Arnold van de Laar JOHN MURRAY *(2018)*
In this witty chronicle, surgeon Arnold van de Laar dissects thousands of years' worth of remarkably gruesome stories. From anaesthetic-free amputations and bloodletting to Albert Einstein's aneurysm, these are key insights into the cut and thrust of medicine.



What Algorithms Want
Ed Finn MIT PRESS *(2018)*
Algorithms saturate the digital universe, from Amazon book recommendations to Uber. Ed Finn will make you reassess how you think about these formulae: not as mere components of code and computations, but shaped by a philosophy, and shaping culture in their turn.

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