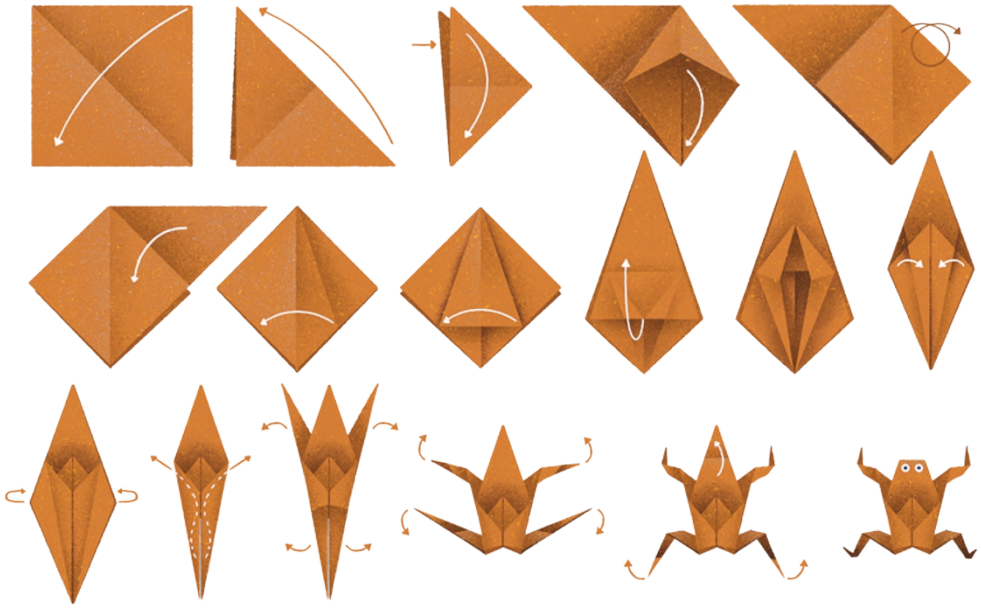


EVOLUTION

Parsing the cycles of change

Mark Buchanan examines a treatise on evolution as central to processes in a vast, varied range of domains.

Evolution is an almost magical idea. First proposed by Charles Darwin in 1859 as an explanation for the manifold diversity of biology, the concept has turned out to be much more profound than its inventor could have imagined. Evolution is a general strategy, or class of strategies, for finding solutions to very difficult problems through iterative, combinatorial exploration in high-dimensional spaces of possibilities. Organisms evolve, and so do algorithms for image recognition or for financial trading.

Matt Ridley, an accomplished science writer and Conservative member of the UK House of Lords, has explored the power of evolution in biology in half a dozen books. In his latest, *The Evolution of Everything*, Ridley makes a powerful argument that evolution in a more general sense has created most of the things that we treasure — from modern technology to decent government and reasonably stable economies. He also ponders the mystery of why, despite this overwhelming evidence for the value of evolution in design, so many people still long for the apparent order of top-down planning and control, solutions designed and implemented by policy experts.

Over 16 chapters, Ridley explores processes that involve incremental change through trial and error. He considers the evolution of the Universe, morality, the economy, technology, money and more — even the future. In each, he examines how attempts to solve human problems through logical planning and purposeful intervention so often fail.

The Evolution of Everything: How New Ideas Emerge
MATT RIDLEY
Fourth Estate: 2015.

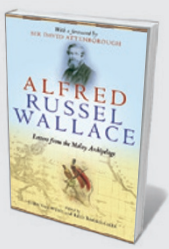
Take overpopulation. In the 1960s and 1970s, a number of writers — most prominently, the ecologist and demographer Paul R. Ehrlich — proclaimed that global famines would soon devastate humanity unless drastic action were taken to stop the population explosion. The problem, one expert suggested, required the creation of a planetary authority with responsibility "for determining the optimum population for the world and for each region". The idea was a non-starter, and even trying to implement it would probably have caused immense suffering. As Ridley argues, it was the evolutionary inventiveness of science and changing human practices that offered a solution, at least temporarily. We found much more efficient agricultural methods, and people, as they grew more prosperous, started to have fewer children.

In this case, and in many others that Ridley examines, solutions to important human issues were discovered not through conscious planning, but through undirected experimentation. We defeated the dark of night through the slow accumulation of many discoveries — fire, the production of metals, the steam engine, vacuum technology and so on — none of which were expressly aimed at illumination. Similarly, nearly all human societies have created powerful, flexible written languages for communication — not by design, but through slow adaptation, adjustment and modification.

Ridley is generally correct. The world is teeming with systems — anything from the Internet to New York City traffic — that

NEW IN PAPERBACK

Highlights of this season's releases



Alfred Russel Wallace: Letters from the Malay Archipelago
Edited by John van Whye and Kees Rookmaaker (Oxford Univ. Press, 2015)
Alfred Russel Wallace led an adventurous life in science, from insect spotting in a Borneo swamp to exploring Ternate island, Indonesia, where he independently developed a theory of natural selection. This collection of correspondence from 1854 to 1862 covers his fateful travels. The letters (which took six weeks to arrive), to and from Wallace's family and Charles Darwin, shed light on the controversy over precedence of the theory, as well as the malaria and other hardships that Wallace suffered for his work.

are much too complex to engineer and control with top-down thinking. And his book offers revealing examples of how evolution has improved approaches across essentially all fields, from software design and telecommunications to the economics of housing and basic human morality. *The Evolution of Everything* will be enjoyed by anyone interested in the origins of order and organization in human societies, and how we might put evolutionary forces to better use in managing our lives and communities.

One thing that I liked less about the book, however, is how Ridley's political views often intrude on his arguments. His examination frequently gives way to complaints about all manner of things that he — a libertarian — despises. Too much government and meddling in health care; too many taxes and layers of social policy to protect people. Ridley manages to blame the good intentions of left-leaning people for the persistence of global poverty, for the demise of the British health-care system, even for fascism. Most of the intelligent public, Ridley grouses, believes that government is the foundation of all that is good, and is generally infallible.

Does anyone actually believe this? Most people just think that government does some necessary and useful things — helping to ensure the stability of the financial system, for example, and providing basic levels of education. Most economists think the same. This aspect of the book will no doubt appeal to the libertarian element in right-wing organizations, but for many readers, the asides will interfere with the discussion.

If you filter out the political cheerleading, Ridley's argument emerges as edifying. It is almost certainly true that solutions to our most pressing problems — from global poverty to climate change — are not going to spring from the mind of any lone genius or planning committee. We will find them through the collective tinkering and evolutionary exploration of tens of millions of diverse minds working together. ■

Mark Buchanan *is a science writer based in Abbotsbury, UK. His latest book is* Forecast. *e-mail: buchanan.mark@gmail.com*

PHYSICS

Two shades of physics

Robert P. Crease contrasts a physicist's account of awe with a historian's reality check.

Seven Brief Lessons on Physics
CARLO ROVELLI
Allen Lane: 2015.

Physics: A Short History from Quintessence to Quarks
JOHN L. HEILBRON
Oxford University Press: 2015.

These two concise tours of physics are delightful, each in their own way. In *Seven Brief Lessons on Physics*, physicist Carlo Rovelli appreciates the field's beauties in an expansion of articles he wrote for the Italian newspaper *Sole 24 Ore*. Science historian John Heilbron's *Physics* surveys the discipline from ancient times to today.

Rovelli begins by relaying his excitement at discovering the general theory of relativity for the first time, in the gnawed pages of a textbook he had used to plug mouse holes. Reading it on a beach in Italy, he was inspired by its disclosure of a simpler, deeper order to the Universe — the gravitational field is not diffused through space, but is space. It was "as if a friend was whispering into my ear an extraordinary hidden truth".

He writes evocatively of the theory's many wonders: exploding universes, space collapsing into bottomless holes, time sagging and slowing and the unbounded extensions of interstellar space rippling and swaying "like the surface of the sea". We are immersed not in an invisible rigid infrastructure, but in "a gigantic flexible snail-shell". The metaphors are vivid, the visions dramatic. When this book was first published in November 2014 in Italy, it outsold E. L. James's blockbuster novel *Fifty Shades of Grey* (Vintage, 2011).

Through chapters on quantum principles, cosmology, particles, quantum gravity and thermodynamics, Rovelli maintains the awestruck tone of a practising physicist. Only in a final chapter on the place of humans "in this great fresco" does this stance lead him astray. It makes it hard to explain why some people struggle to comprehend science, and even distrust it. It tempts him into scientism — regarding the world that science describes as the real one. The flow of time, he suggests, is "absent from descriptions of the world". Yet philosophical 'lived time' — the process of anticipating the future out of a past to allow the human experience of the present — is a fundamental condition of being human. It allows us, among other things, to create and marvel at scientific frescos. Placing himself as observer rather than participant, Rovelli forgets where he stands.

THE FLOW OF TIME IS ABSENT FROM DESCRIPTIONS OF THE WORLD.

Heilbron's *Physics* is different in topic and tone. He uses the Greek word *physica* to name the ancient field, then traces how it morphed into physics. *Physica* seamlessly folded in astronomy, psychology and zoology; its idea of cause included form, purpose and the stuff of which things were made, as well as pushes and pulls. From this, Aristotle developed a 'theory of everything', which explained almost all phenomena experienced by humans, from the growth and behaviour of plants and animals to the patterns made by heavenly bodies. It included a deity that drew things into motion; ▶

The Quantum Moment
Robert P. Crease and Alfred Scharff Goldhaber (W. W. Norton, 2015)
Philosopher Robert Crease and physicist Alfred Goldhaber reveal how quantum theory has pervaded popular culture, from quantum poetics to television's *Quantum Leap* (see Jim Baggott's review: *Nature* **513,** 308–309; 2014).

Adventures in the Anthropocene
Gaia Vince (Milkweed, 2015)
The human epoch is in full swing, with a population of 8 billion looming. In search of sustainability, journalist Gaia Vince travelled to six continents and found much to foster hope — such as the Ugandan farmer who feeds livestock on a by-product of her sunflower crop.

and 'quintessence', a fifth element (in addition to the familiar earth, air, fire and water), which was needed to keep the theory consistent, explaining, for example, why heavenly bodies move in circles rather than in straight lines.

Physica did not become physics simply as a result of observant people adding pieces to a puzzle. It required transformations in the social ecosystem, such as who pays for knowledge and why; its social applications; and how it is communicated. *Physica* got a big boost from the Islamic world, where Aristotle's concept was highly regarded and translated into Arabic around the ninth century. But physics began to acquire its eventual outline in the West after the sixteenth century, with the generation of Francis Bacon, Galileo and René Descartes.

Fostered by the needs of centralized, bureaucratic states, the discovery of new worlds, the spread of universities and new industrial applications, the emergence of physics as we know it today was a process of "dedeifying and deanthropomorphizing nature". Now, God is marginalized and 'dark energy', our new quintessence, is needed to make sense of it all. A theory of everything is an ever more remote goal.

Heilbron does not sneer at *physica,* but carefully examines it and the ecosystem in which it thrived. By the book's end, physics has split off into so many branches — radar, Earth science, space probes, accelerators, meteorology and so on — permeating so many spheres of human life that we begin to lose sight of the field as something coherent. And that is the point.

Whereas Rovelli's feel-good book ends with us gazing in wonder at the edge of "the ocean of the unknown", Heilbron leaves us rooted in lived reality. "Physics has given civilization a somber, disturbing, and challenging world picture, many fertile and some terrifying inventions, and notice of responsibility for the outcome of the human story." If it, too, outsells *Fifty Shades*, there is hope for humanity yet. ■

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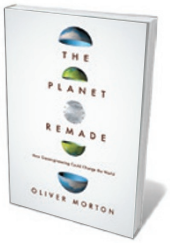
GEOENGINEERING

Journey into geopoetry

Jane C. S. Long relishes an erudite exploration of the people and principles of climate intervention.

Several authors have tackled geoengineering — the idea of harnessing science and technology to cool our overheated planet. In the 2010 *How to Cool the Planet* (Houghton Mifflin Harcourt), Jeff Goodell told the personal stories of geoengineers. One, physicist David Keith, described how his interest in climate modification is grounded in a desire to preserve nature in *A Case for Climate Engineering* (MIT Press, 2013). Jack Stilgoe discussed responsible governance of geoengineering in *Experiment Earth* (Routledge, 2015). Eli Kintisch covered the history of potential solutions and their developers in *Hack the Planet* (Wiley, 2010). Stewart Brand described intervention as inevitable in *Whole Earth Discipline* (Atlantic, 2010), stating: "We are as gods and we might as well get good at it."

But if you are going to read one book on climate engineering, it should be *The Planet Remade*. Oliver Morton, briefings editor at *The Economist*, starts by asking: do you think climate change is a problem, and the energy system easy to change? Using this dialectic, he explores the thesis that the climate crisis cannot be solved, but could be managed. There follows a journey through the people and principles of climate science and intervention, the natural history of carbon dioxide, engineering of the nitrogen cycle and the backstory of weather modification. Morton speculates about the ethical, political and social implications if climate intervention became available. The book finishes with a range of scenarios — including one that could end well for Earth and a frank discussion of what could go wrong. *The Planet Remade* is as much an exploration of science and engineering as it is of people and attitudes.



The Planet Remade: How Geoengineering Could Change the World
OLIVER MORTON
Granta: 2015.

Most climate engineering proposes to change the radiation balance of Earth so that less radiation gets in, or more escapes. Techniques include spraying reflective aerosols into the stratosphere, brightening clouds with salt spray or sequestering greenhouse gases.

Morton traces the idea to the cold war, when scientists including physicist Edward Teller began to fear that a nuclear war would cause a hellish conflagration, darkening the skies and creating a 'nuclear winter'. Efforts to understand this led to the birth of modern climate science — which in turn supported 1980s warnings about climate change by the likes of atmospheric physicists James Hansen and Stephen Schneider. Given clear evidence that volcanic eruptions can send enough reflecting sulfur particles into the stratosphere to cool Earth noticeably, it was not a great leap for some scientists to contemplate intentionally using sulfur to counteract greenhouse-gas emissions. *The Planet Remade* encourages researching this idea and others to learn more about their effectiveness, feasibility and advisability.

Climate engineering evokes very disparate and strong reactions. As Morton shows, some people, such as Keith, are keen to start intervention, whereas others, such as ethicist Clive

The Naming of the Shrew: A Curious History of Latin Names
John Wright (Bloomsbury, 2015)
Ba humbugi is not a curse but a snail, and bananas are a "taxonomic nightmare". Fungus fanatic John Wright digs into taxonomy's origins, including Carl Linnaeus's overtly sexual plant-ordering system, based on reproductive parts.

The Body Keeps the Score: Brain, Mind, and Body in the Healing of Trauma
Bessel van der Kolk (Viking, 2015)
Violence, abuse or conflict can burn trauma into memory. Psychiatrist Bessel van der Kolk reveals how severe stress rewires the brain, and suggests therapies from breathing techniques to eye-movement desensitization and reprocessing.

Hamilton, abhor the enterprise. Brand feels that the only option is to manage the global environment — which many fear would fail, because humanity lacks the wisdom and capability for the task. Morton weighs these perspectives with sympathy. He takes pains to find value in each, while maintaining his own insight gleaned from knowledge of the natural world, social thought, literature and science fiction, science and politics, scientific history and the scientists making that history. Lively anecdotes make clear that, as a journalist, Morton has known many of these people personally. Who else could tell us that the substance ice-nine in Kurt Vonnegut's novel *Cat's Cradle* (Holt, Rinehart & Wilson, 1963) was based on cloud-seeding research by the novelist's brother, Bernie?

His prose is sometimes hard to parse, but poetic — or "geopoetic", as he would have it. In a moving passage, Morton explains that he has not said "we" because the world population has yet to unite to counterbalance climate change, although he hopes that it will. His hope is embodied in the beauty of elegant engineering and joy in a world of thriving life:

THE WORLD POPULATION HAS YET TO UNITE TO COUNTERBALANCE CLIMATE CHANGE.

"a reimagining of how humans and nature can intermingle, a new consciousness of what can be done for the planet rather than a blind deference to what are claimed to be its limits". He sees the future as creating "a we … that can set a better course". I share Morton's belief that contemplating climate intervention could help humanity to become a "we" that acts on the need to take responsibility for our planet, with or without geoengineering.

For a potentially harrowing topic, serendipity and fun abound. Plentiful and erudite footnotes are richly entertaining. To quote a favourite, in discussing controversy over defining the start of the human-influenced Anthropocene epoch, Morton notes: "when scientific publications refer to an event happening 2,500 or 5,000 years 'before present' (BP), they actually mean before 1950. If 1950 were chosen as the beginning of the Anthropocene, then the Anthropocene would … be in a condition of permanent futurity, hanging unsupported in the air like a Wile E. Coyote that has run over the cliff at the end of history."

Who should read *The Planet Remade*? In some ways it is too technical for a lay audience, but too important to be reserved for experts. Anyone with a knowledge of the climate problem would benefit; it also works as a primer on energy, climate science and Earth-system science. I have a long list of people to whom I will be recommending it. ■

Jane C. S. Long *works on reinvention of the energy system and geoengineering. She has retired as associate director for energy and environment at Lawrence Livermore National Laboratory in California, and was formerly dean of the Mackay School of Mines at the University of Nevada, Reno.*
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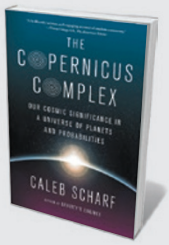
From Eve to Evolution
Kimberly A. Hamlin (Univ. Chicago Press, 2015)
Science historian Kimberly Hamlin shows how nineteenth-century US feminists used Darwinian evolutionary theory to argue for equality. Eliza Gamble, for example, put women's choice at the forefront of male–female attraction (see Sarah S. Richardson's review: *Nature* **509,** 424; 2014).



The Copernicus Complex
Caleb Scharf (Farrar, Straus and Giroux, 2015)
Are we cosmically insignificant or the centre of the known Universe? Skipping from molecules to Moon landings, astrobiologist Caleb Scharf puts life on Earth under the microscope and concludes that humans are unique but unexceptional (see Mario Livio's review: *Nature* **512,** 368–369; 2014).

COSMOLOGY

A story of cosmic proportions

Michael S. Turner weighs up two distinctive popular books on the evolution of the Universe.

Jim Baggott's *Origins* and Lisa Randall's *Dark Matter and the Dinosaurs* recount the greatest story ever told: the evolution of the Universe since the Big Bang. This rich cross-disciplinary tale reminds us that astronomy, physics, chemistry, geoscience, biology and neuroscience are interconnected. The books cover the same ground in very different styles. Baggott, a chemist turned science writer, takes the reader on a linear, 13.8-billion-year journey. His textbook-like treatment abounds with excellent visuals, from charts to lithographs. At its best, *Origins* reminds me of Richard Holmes's marvellous *The Age of Wonder* (HarperCollins, 2008).

Randall, a particle physicist and cosmologist, makes the epic trip more succinct and conversational, interspersing her passions, perspectives and creative analogies. Describing how astronomers 'see' dark matter, she uses the analogy of knowing that a celebrity is near because of disrupted traffic and crowds of phone-wielding people. Her strong opinions — even ones I question, such as suggesting that "transparent matter" might be a better name than dark matter — liven the narrative.

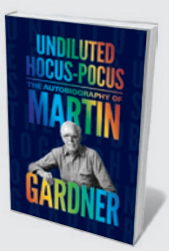
The story begins with the Big Bang. What it is — the origin of matter, energy, space and time as Einstein's general theory of relativity has it, the emergence of space and time as string theory might posit, or the outcome of a previous cycle of cosmic evolution — remains to be determined. Inflation follows: a burst of expansion that smooths and flattens the Universe and stretches quantum fluctuations to astrophysical size, to become the seeds for all structure in the Universe. The details have yet to be revealed. But evidence for inflation is growing, particularly in measurements of tiny variations in the temperature of the cosmic microwave background radiation.

This 'quark soup' phase lasts a microsecond, followed by nucleosynthesis and the formation of the lightest elements at 3 minutes. Atoms form at 380,000 years. Then gravity amplifies lumpiness in the distribution of matter to become galaxies, clusters of galaxies and superclusters, with the first stars and galaxies emerging at around 500 million years. The Sun forms some 9 billion years later.

Now the narratives turn to 'local' events: Solar System formation, Earth's cooling, the emergence of oceans — and, 3.5 billion years ago, the first life forms. Important questions remain. Where did organic material originate? How did the transition from inorganic to organic occur? What was the last universal common ancestor, which Charles Darwin described as the primordial form from which all living things on Earth descend? From here, the pace quickens: multicellular organisms, atmospheric oxygenation around 2.5 billion years ago, sex as a mechanism for gene exchange, the emergence of primates shortly after the dinosaurs' demise and,

Origins: The scientific story of creation
JIM BAGGOTT
Oxford University Press: 2015.

Dark Matter and the Dinosaurs: The Astounding Interconnectedness of the Universe
LISA RANDALL
Ecco: 2015.



Undiluted Hocus-Pocus
Martin Gardner (Princeton Univ. Press, 2015)
Zealously debunking science fads and declaring his bafflement at the human brain, maths writer Martin Gardner was on fine form in this posthumous memoir. As it reveals, his *Scientific American* column was just a piece of his life's puzzle (see David Singmaster's review: *Nature* **501,** 314–315; 2013).

Junk DNA
Nessa Carey (Icon, 2015)
If only 2% of human DNA is technically 'useful' in coding for proteins, what is the other 98% for? Geneticist Nessa Carey uses Jackson Pollock paintings and baseball bats to explain how 'junk' DNA keeps the body functioning (see Nathaniel Comfort's review: *Nature* **520,** 615–616; 2015).

some 200,000 years ago, *Homo sapiens*.

Baggott ends at consciousness, that frontier of interdisciplinarity. But he fails to ask whether intelligent life is a convergent property of evolution. Given that evolution involves dominating local resources, the Universe may teem with 'dumb' life, while intelligent life remains exceedingly rare.

Earth's prehistory was marked by five major extinctions, identified in 1982 by palaeontologists David Raup and John Sepkoski. The Cretaceous–Palaeogene extinction 66 million years ago, which killed the dinosaurs, is the best known. Physicist Luis Alvarez and his geologist son Walter proposed that the cause was an asteroid impact, an idea met with scepticism until the mid-1990s, after a crater fitting the bill was identified in Mexico. Such an impact can alter conditions on Earth for tens of years, through a global dust cloud, firestorms and other after-effects: species ill-suited to such dramatic change go extinct.

Raup and Sepkoski also put forth evidence that extinction events occur roughly every 30 million years. This is now generally accepted, but there is no agreed mechanism. Randall and her collaborator Matt Reece offer a hypothesis. They posit that there are two kinds of dark matter: the ordinary one, whose gravity binds galaxies and galaxy clusters, and a 'social' form that also interacts with its own kind. The social dark matter forms a thin disk of material in our Galaxy whose gravity can shake things loose in the outer depths of the Solar System when it crosses the Galactic disk, every 30 million years or so. Randall admits that the idea is a long shot, although testable. This aspect of *Dark Matter and the Dinosaurs* conveys the excitement and uncertainty of cutting-edge, big-idea research.

In a chapter called 'The cosmic imperative', Baggott implies that the evolution of life is an inevitable consequence of chemistry, despite our not knowing precisely how it occurred. This reminded me of physicist Murray Gell-Mann's dictum "Everything not forbidden is compulsory" (borrowed from novelist T. H. White), which describes the importance of symmetry principles in particle physics: they set the basic rules, but not the detailed outcomes. A rich set of rules (think chess) can lead to complex and interesting outcomes. I would take this further: the Universe is governed by physical laws that permit a rich set of behaviours, resulting in its inevitable evolution from vacuum energy to quark soup, nuclei and atoms, all the way to the emergence of life and self-awareness. But that does not explain where space, time and the laws came from, or why there is something rather than nothing.

I have quibbles with Baggott's book. He gives a dated picture of inflation (tying it to symmetry breaking), gets the temperature of the cosmic microwave background wrong (it is 2.7255 kelvin) and calls the lumpiness that led to the formation of cosmic structures anisotropy, rather than inhomogeneity. But these gaffes do not interfere with the larger narrative and are a by-product of his sweeping scope and detailed description.

The longing to understand our place in the cosmos is universal. Baggott and Randall lay out how much of the story we understand, and how interconnected it all is. They remind us that big questions remain in this most wonderful scientific adventure. ■

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NEUROSCIENCE

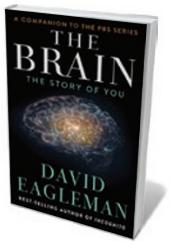
The mechanics of mind

Daniel Bor enjoys a sophisticated study of how the meat in our skulls generates the self.

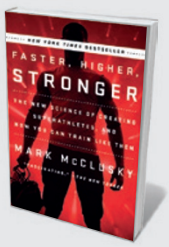
In my bolder moments, I consider neuroscience to be one of the most fundamental scientific fields. The brain is, after all, the location of our experiences and identities, and our main tool for understanding every facet of the Universe. *The Brain* by neuroscientist David Eagleman ambitiously promotes this view. Built around a series of fundamental questions, such as "what is reality?", it calls on a wide range of classic and recent findings, including innovative experiments by Eagleman himself, to demonstrate how brain science is optimally placed to answer those questions.

Eagleman begins by arguing that the brain determines who we are, and how we change. He illustrates just how dramatic such changes can be through the case of Charles Whitman, who in the 1960s switched from mild-mannered bank clerk to violent murderer because of a small tumour pressing on his amygdala, an area of the brain linked to aggression and fear.

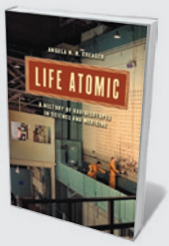
Although the brain's development has a disproportionate role in human identity, with synaptic pruning in infancy a key shaping factor, our brains remain plastic throughout our lives. Eagleman demonstrates this with the well-known example of London taxi drivers found to have enlarged hippocampi — key to memory consolidation — after memorizing thousands of the capital's streets. Memory is the bedrock of our identities, but Eagleman highlights how the past is very much a reconstruction bordering on mythology. A case in point is the relative ease with which false memories can be implanted. The emerging picture is far removed from one ▶



The Brain: The Story of You
DAVID EAGLEMAN
Pantheon: 2015.



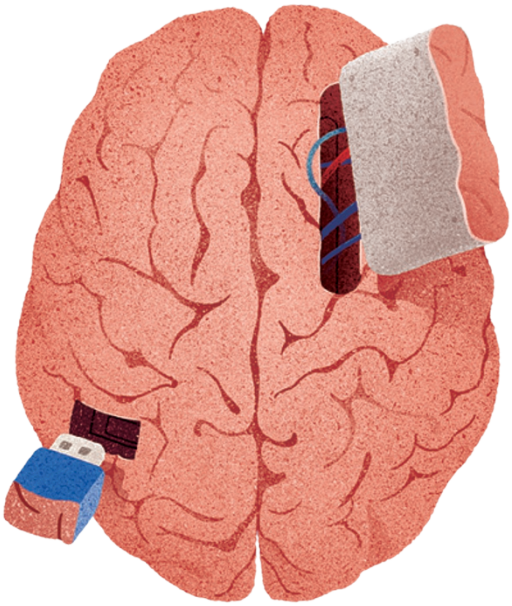
Faster, Higher, Stronger
Mark McClusky (Plume, 2015)
From the primitive "bag-and-valve" apparatus used to measure runner's oxygen intake in the 1920s to today's Silicon Valley performance labs, Mark McClusky shows how sports science has helped humans to push their physical limits, and why we keep striving to beat the best.



Life Atomic: A History of Radioisotopes in Science and Medicine
Angela N. H. Creager (Univ. Chicago Press, 2015)
Radioisotope by-products of atomic energy are vital to molecular biology. Historian Angela Creager archives atoms, from carbon-14 and its role in studying photosynthesis to slow-decaying iron-59, which traces nutrients metabolizing in the body.

in which we have a single personal identity. Instead, he notes, "from cradle to grave, we are works in progress".

Everyone's world view, then, is fallible. Eagleman extends that idea by focusing on perception. We tend to assume that we have a direct connection to what is out there, and that all that we experience is all there is, but the truth is very different. He writes how "every sight, sound, smell — rather than being a direct experience, is an electrochemical rendition in a dark theater". But we are not experiencing a continuous flow of sight and sensation. We sample the world through saccades — jumping visual snapshots. From these, the brain constructs a continuous narrative heavily biased by expectations. We believe this narrative implicitly, even when it goes horribly wrong, such as in schizophrenic delusions.



In light of the idea that our view of our own minds is also deeply skewed, Eagleman challenges the primacy of consciousness. With most forms of expertise, such as driving, the conscious mind merely gets in the way. Furthermore, unconscious influences on our decisions are pervasive. For instance, judges deciding whether to award parole to prison inmates are more likely to do so if they have eaten beforehand. Decisions are little more than the product of unconscious neural battles between competing drives. Eagleman uses this stance to argue for an end to the catastrophic US war on drugs that began in the 1970s, and to call for more sympathy for, and (neuroscientific) understanding of, the plight of people addicted to drugs. He is helping addicts to reduce cravings by getting them to retrain their brain activity through neurofeedback in a functional magnetic resonance imaging scanner. They can view real-time summaries of the relative activities of their "craving" and "suppression" brain networks, and can practise strategies to discover the most effective way of suppressing cravings.

What of our relationships with others? Here, Eagleman notes that "what we demarcate as you is simply a network in a larger network". He describes how social exclusion can, like physical harm, activate pain centres in the brain such as the insula. Empathy, neurally speaking, invokes emotions as if we were experiencing for ourselves the events that we see others experience. However, when we consider members of "outgroups" to which we have no social ties, our empathic and social neural responses are flattened — as if we were dehumanizing them. This, Eagleman argues, is the neural mechanism that allows us to switch from being friendly to neighbours to wanting to wipe out their entire ethnic group, as for instance happened in the Bosnian war of the 1990s. Eagleman suggests that education about the neural underpinnings of our responses to outsiders is key to reducing the chance of genocides.

Eagleman ends by considering the future of humanity, and how neuroscience can technologically reshape almost every aspect of our lives. Although by far the most speculative part of the book, this is also the most fascinating. Eagleman describes the senses as flexible "peripheral plug-and-play" devices, with the brain not caring what input it receives as long as it is useful. We already exploit this feature with cochlear and retinal implants for people who have hearing or visual impairments. How much further can we take it?

Eagleman and his graduate student Scott Novich have developed an electronic vest that provides tactile feedback to the torso through arrays of small vibrating motors, and are testing it on people with impaired hearing, to allow them to 'hear' through touch. The vest could be used for almost any real-time information stream, such as weather, stocks or altitude readouts in plane cockpits. And enhancing senses is only half the story: if we can control a robot arm through motor-cortex activity (see *Nature* **497,** 176–178; 2013), could someone check their e-mails while their brain–computer interface manages a vacuum cleaner?

Throughout, Eagleman provides multiple, varied explanations for what consciousness is and what it is for; he settles on neuroscientist Guilio Tononi's integrated information theory. This equates high levels of consciousness with information that is widespread throughout a network capable of supporting many different information states. Tononi's theory is consistent with the possibility of uploading our minds into computers. Without being limited by our fragile biology, we might feasibly travel to extrasolar worlds, "pausing" the computer simulation of our minds on the bulk of the journey to avoid boredom. Although such ideas are immensely fun to imagine, to computationally capture our brains we would have to be able to read every cellular detail of this incredibly complex organ — a feat that is centuries away, if it will ever be possible.

With such exciting themes, *The Brain* — a companion book to Eagleman's upcoming six-part television series of the same name on the US Public Broadcasting Service — is an ideal introduction to how biology generates the mind. Readers familiar with this field will be revisiting a range of classic research, and might feel frustrated that more depth is not given in places. The science, however, is structured around crucial and wide-ranging questions, saturated with personal and social relevance. And Eagleman's answers are consistently clear, engaging and thought-provoking. ■

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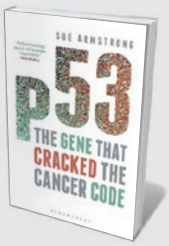
Odd Couples
Daphne J. Fairbairn (Princeton Univ. Press, 2015)
As biologist Daphne Fairbairn observes, males and females of one species can differ greatly in colour, size and shape. Blanket-octopus females, for instance, outgrow males by 2 metres, quashing the dominant-male stereotype (see Suzanne Alonzo's review: *Nature* **496,** 427–428; 2013).



p53: The Gene that Cracked the Cancer Code
Sue Armstrong (Bloomsbury Sigma, 2015)
From its discovery in 1979 to its current place in cutting-edge gene therapy, p53 is the most studied gene in history. As Sue Armstrong details in this chronicle of genetics derring-do, its crucial role is to protect us from cancer, and the future of tumour treatment could depend on it. **Emily Banham**