lecturers. Throughout most of the book, the mathematical essentials could be appreciated without adopting that approach, but its advantages are considerable when the authors discuss the fields in which they are international leaders — general relativity, black holes and high-energy astrophysics.

All that said, I was constantly thinking about how I would have presented the same material using more elementary techniques. In my view, simpler, perhaps more intuitive, approaches can help students to appreciate the greater power of the methods adopted in this book, and would reinforce the new graduate student's capacity to master the material. For instance, Thorne and Blandford's geometrical approach leads directly to the invariant number density of states in phase space in relativity. I derive the same result more primitively, by considering the various aberration effects involved in observing a relativistically moving black body; in this way, the student appreciates more about aberration effects in relativity, as well as about a key relativistic invariant. This is not a criticism, but rather an example of the advantages of adopting multiple approaches.

The book becomes more demanding as it progresses through the subjects. The final section, on general relativity, is perhaps the most challenging, as the authors are well aware. However, their many insights are certainly worth the effort, for example in understanding the physics close to the event horizon of a rotating black hole. In the final chapter, they drop their pedagogical mantle and bring everything together in a synthesis of understanding of contemporary cosmology. This is authoritative and should be supplemented by the many excellent books on the subject — there is a vast amount of detailed physics to be mastered.

How is this book going to be used? Many separate courses could be created from it. I suspect that, as with the Feynman lectures, professors will love the approach, whereas most students will appreciate its brilliance only once they have assimilated the material through independent reading. That is what I recommend: take one of the sections and enrich it with supplementary reading (the authors make ample suggestions). Then repeat the process several times, with a progressively deeper understanding each time. ■

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CHEMISTRY

Explosive moments in the laboratory

Mark Peplow surveys a gorgeous gala of reactions in Theodore Gray's new book.

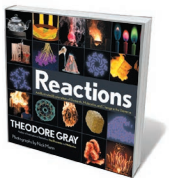
For Theodore Gray, chemical reactions are "a sort of nanoscale fight club". In *Reactions*, the chemist, science writer and technologist offers a lavishly illustrated tour of this molecular battleground, full of wit and wonder.

Gray's career as a chemical evangelist began in 2002, when he misread a line in Oliver Sacks's *Uncle Tungsten* (Knopf, 2001) and imagined the periodic table of elements as a literal table. A skilled woodworker, Gray decided to build it and stock cavities beneath each symbol with samples of the elements.

Then, he recalls, "things really got out of hand" (go.nature.com/2fdcm9b). The table won the 2002 Ig Nobel Prize in Chemistry, and spawned a cottage industry: Gray now sells periodic-table posters, books and quilts, and makes museum displays. With photographer Nick Mann, he has amassed a gallery of element photos, showcased in his 2009 book *The Elements*. Its sequel, *Molecules*, followed in 2014; *Reactions* is the final part of the trilogy (all published by Black Dog & Leventhal).

Gray's enthusiasm shines in *Reactions*. Take the humble glow stick, which mixes two precursors to generate a peroxyacid ester that jolts a dye into emitting light. Of this, an object available at petrol stations for a pittance, he urges: "I insist that you be amazed." The text is peppered with dry asides, and a grumpy disdain for anything unscientific. Homeopathy he brands authorized lying; claims for 'chemical-free' health foods irk him. Even steampunk — gadgetry with a Victorian aesthetic — draws his ire, because "none of the things these people make actually work".

So far, so enticing. Yet the book struggles to sustain momentum because it lacks a narrative. In *The Elements*, the organizing principle was obvious: it was a beautiful catalogue of the building blocks of matter, ordered by atomic number and full of fascinating facts. But chemical reactions are messy and multitudinous. It can be hugely challenging to explain why they occur, and to choose which to include.



Reactions: An Illustrated Exploration of Elements, Molecules, and Change in the Universe
THEODORE GRAY
Black Dog & Leventhal: 2017.

NICK MANN

Aluminium foil reacts with bromine.

Reactions leans heavily on combustion and explosion — understandable, given its visual emphasis. As a result, some of it feels samey. Plenty of other glamorous reactions could have illustrated different concepts, from the redox chemistry behind the spectacular ammonium dichromate 'volcano', to the catalytic decomposition of hydrogen peroxide used to create 'elephant's toothpaste' — a foam fountain beloved of science demonstrators.

When Gray settles on a subject, he can provide genuine insight, as in sections on the anatomy of fireworks or the composition of paints. But too often, the coverage is frustratingly superficial. In the sole example from the vast field of synthetic organic chemistry, he outlines the total synthesis of the alkaloid physostigmine, yet divulges nothing about why it is useful — it's a treatment for glaucoma. And although the diagrams that show its step-by-step construction create an impression of complexity, Gray doesn't begin to explain why this particular route is a

cunning way to knit together a molecule. It's enough to spark, but not sate, curiosity.

Delving into the principles behind reactions, Gray follows the Sun's energy from chlorophyll to plant carbohydrates, and onwards to oil, petrol and the chemistry of the internal-combustion engine. This discussion of energy is straightforward ("an itch that the universe needs to scratch"); the coverage of entropy is more difficult to follow. "Feel free to skip this section, by the way: it's really hard," he writes. From a science communicator, that feels like a cop-out.

There are brief mentions of how other factors — concentration, temperature, surface area — affect rates of reactions, but no unifying explanation of chemical kinetics to go with the thermodynamics. Catalysis, surely one of the most important principles of modern chemistry, is notably absent.

Still, it feels churlish to gripe about this love letter. Mann's photography transforms chemical samples into art, and captures the thrill of Gray's demonstrations. Many photos recall the works of eighteenth-century artist Joseph Wright, using chiaroscuro to frame the glow of a reaction with a background of deep shadow. Others are playful: in one, chlorine gas combines with sodium metal to create a billow of sodium chloride, which rises to vaporously salt a net full of popcorn.

The pictorial treats go beyond photography. Molecular structures are bathed in a diffuse violet glow, the shimmer serving as a reminder that their shroud of electrons is a cloud, not a constellation of points. And the most attractive chapter, on the chemistry of light, draws a beautiful analogy between sound waves and musical notes, and electromagnetic wavelengths and colour.

There are gorgeous sequences of stills from high-definition video, such as one showing the hellish cauldron created when aluminium meets bromine. I had an urge to jab the page to make it play. Indeed, Gray's previous works have been ported, extremely successfully, into iPad apps, with multimedia that users can manipulate. I expect that *Reactions* will make the same transition. For now, it feels like an app trapped inside the body of a book. ■

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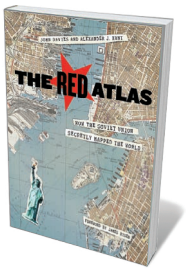
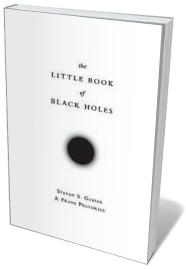
CORRECTION

The Books & Arts article 'Final ascent of physics' (*Nature* **549,** 331–332; 2017) incorrectly stated that *Special Relativity and Classical Field Theory* is the last book in the Theoretical Minimum series, and described it as "historical" instead of "ahistorical". The text and title have been corrected.

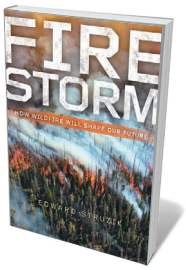
Books in brief



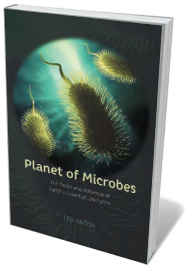
The Red Atlas: How the Soviet Union Secretly Mapped the World
John Davies and Alexander J. Kent UNIVERSITY OF CHICAGO PRESS *(2017)*
It stands as one of the most astounding feats of twentieth-century cartography. From 1950 to 1990, Soviet spies and satellites surveyed most of the planet to create what may be more than one million military maps, so detailed they show the composition of bridges and species of trees. As John Davies and Alexander Kent reveal in this glorious homage embellished with 350 map extracts, the gargantuan project might have been groundwork for a cold-war coup. Ironically, its near-comprehensive coverage has proved a boon for Western surveyors working in otherwise uncharted territory.



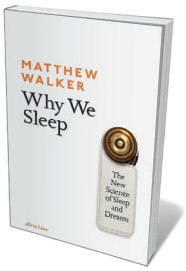
The Little Book of Black Holes
Steven S. Gubser and Frans Pretorius PRINCETON UNIVERSITY PRESS *(2017)*
The first faint chirp recorded by the Laser Interferometer Gravitational-Wave Observatory (LIGO) in September 2015 marked the momentous merger of two black holes. And it's to these astrophysical regions of no return that physicists Steven Gubser and Frans Pretorius devote their slim primer. After extolling black holes as theoretical laboratories, they trek through relativity, Schwarzschild black holes and beyond. The thrills come thick and fast, not least when a hypothetical probe nearing a singularity is "squished and stretched into an infinitesimally thin line".



Firestorm: How Wildfire Will Shape Our Future
Edward Struzik ISLAND *(2017)*
Starting in May 2016, a huge wildfire devastated Fort McMurray, Canada. Dubbed the Beast, it burnt more than 566,000 hectares and displaced 88,000 people. And it is a sign of heated times: a new wildfire paradigm is emerging in North America's boreal forests, already pressured by fracking, logging and insect infestations. Edward Struzik's deft account interweaves reportage, science and policy to show how fires that are normally key to ecological resilience are growing bigger and faster, thawing permafrost, degrading watersheds and disrupting habitats of species from grizzly bears to fungi.



Planet of Microbes
Ted Anton UNIVERSITY OF CHICAGO PRESS *(2017)*
Collectively, Earth's microbial hordes are its dominant life form. A realm that spans the mammalian gut, the ocean floor and the International Space Station is a rich one, and discoveries in it continue to rattle and revivify biology. Ted Anton's captivating narrative follows the field's evolution through key findings in symbiosis, archaea and the microbiome by inspired scientists such as Lynn Margulis, Carl Woese, Margaret McFall-Ngai and Elaine Hsiao. Anton dips, too, into how the findings are influencing diet, agriculture, medicine and environmental sustainability.



Why We Sleep: The New Science of Sleep and Dreams
Matthew Walker ALLEN LANE *(2017)*
If your nightly snooze lasts less than seven hours, you risk weakening your immune system, messing with your metabolism and depriving yourself of a "consoling neurochemical bath". So argues neuroscientist Matthew Walker, who draws on current research to demystify sleep, traverse the wild world of dreams and disentangle sleep disorders. From an infant's polyphasic snippets of slumber to the "hyper-associative problem-solving benefits" of REM dreaming, Walker's investigation is anything but soporific. **Barbara Kiser**