Light: A Radiant History from Creation to the Quantum Age
BRUCE WATSON

Bloomsbury: 2016.

Aurora: In Search of the Northern Lights

MELANIE WINDRIDGE

William Collins: 2016

Watson's book is an eye-catching display, reflecting and refracting like a gemstone. One moment we are among late-nineteenth-century Parisians watching the cinematograph of the Lumière brothers (was there ever a better example of nominative determinism?). The next we are examining Rembrandt's 1642 painting *The Night Watch* — which depicts a militia emerging into the light — or commiserating with modern astronomers about light pollution. This is all tremendous fun, but never quite focuses into a coherent image. Perhaps light has too many facets to offer unifying themes. However, like other mythologically charged substances (such as water and gold), it does not easily shed its associations under scientific scrutiny. That may be why transformation optics has become a 'technology of invisibility' and quantum optics claims to promise teleportation. The electromagnetic ether was once considered a possible bridge between the physical and spiritual worlds; in a way, light still holds that allure.

Nowhere is that more apparent than in the phenomenon of the aurora borealis, or northern lights, produced when subatomic particles in the solar wind collide with molecules in the atmosphere at Earth's magnetic pole, stimulating emissions of light. Plasma physicist Melanie Windridge embraces the aurora's magical quality even as she attempts to unravel the science. She has camped at temperatures approaching -40°C in Svalbard,

Sunlight streaming through windows at New York City's Grand Central Terminus.

Norway's Arctic archipelago, to experience the visceral thrill of seeing these shimmering curtains. It is clear in this captivating book that her technical understanding has not dimmed her delight.

Windridge's account explains what we do and do not yet know about the auroras, and how this understanding has evolved. The journey takes in the restless, violent activity of the Sun's outer layers, the physics of interaction between the plasma of the solar wind and Earth's magnetic field, the atomic physics that generates the various colours of the aurora (oxygen produces the predominant green and red, nitrogen the rarer blue and purple) and the potential of auroral monitoring (for

instance, of changes in shape) to provide advance warning of disruption to telecommunications caused by stormy "space weather".

What emerges is the tremendous difficulty of formulating intuitive and predictive models of a turbulent and chaotic process. The auroral morphologies are described even now in qualitative terms — arcs, veils, rays and so forth — and a full theory is still lacking. Windridge makes a persuasive case that the quest to find one is both pragmatic and inspired by the visual majesty of nature's light. ■

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ENGINEERING

Broken bridges and highways from hell

Kyle Shelton applauds a study that probes the parlous state of US infrastructure.

In *The Road Taken*, engineer and historian Henry Petroski surveys the state of US bridges, roads and tunnels — the legacy of two centuries of technological development — and finds them crumbling. Echoing Robert Frost's poem 'The Road Not Taken', Petroski reflects on both physical highways and the choices that contributed to their current state. As Frost wrote, "Two roads diverged in a wood, and I—/I took the one less traveled by,/And that has made all the difference." Petroski compellingly shows that only by closely investigating the figurative roads down which the country has travelled,

and the decisions made at their forks, can the past be used to shape the future.

Some of those paths, he reveals, have been revolutionary — from the advent of asphalt for road construction in 1870 to the quest for autonomous cars. Some have thrown up obstacles that affect future choices: expensive projects, huge maintenance demands,

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short-sighted political decisions and lacklustre design. Petroski shows how the choices of policymakers and engineers contributed

to soaring successes such as the Golden Gate Bridge in San Francisco, California, and tragic failures including the 2007 collapse of the I-35W bridge in Minneapolis, Minnesota, which killed 13 and injured 145.

A typical history of US transport infrastructure would begin with the travel revolution of the early nineteenth century. This spawned the steamship, New York's Erie Canal and the first federally funded highway, the National Road. Then followed railways, bicycles and the early-twentieth-century boom in automobiles and road construction.

Petroski touches on much of this, as well as

infrastructure below ground. In an opening vignette about his Brooklyn childhood, he highlights the contradictory nature of all that cabling and piping — simultaneously invisible and utterly necessary, the ever-present context of our daily lives, carrying electricity, waste, water and gas to and from our homes. But his focus is the structures and elements of the ever-evolving road.

He delves into the progression of road surfaces from carefully stacked stone to tarmac, concrete and asphalt, in the unending quest to make smooth, durable surfaces. He shares the history of modal conflict — between horse-powered vehicles, pedestrians and automobiles — by looking at how safety features and traffic signals developed. Finally, he discusses materials failure not only through how steel and concrete deteriorate, but by connecting that decay to financial and political choices that undervalued risk. There are more than 6 million kilometres of public roads in the United States, and its citizens travel nearly 5 trillion kilometres a year on them. But as the American Society of Civil Engineers reported in its 2013 'report card' on US infrastructure, 66,749 US bridges (1 in 9) are structurally deficient, and 32% of US roads are in "poor or mediocre condition".

Petroski shows how past practices ripple forwards. Details paint a rich, sometimes pungent, history: for example, woodblock roads (first used widely in the mid-nineteenth century) fell out of favour because they absorbed horse urine. On the country's notorious scourge of potholes, Petroski describes how the combined forces of heavy traffic, water and freezing temperatures conspire to create spreading cracks and distortions in asphalt. He concludes by casting forwards to future roads. Here, he opines, self-driving cars will create safer roads by calculating hazards faster than human drivers can. Asphalt could be revolutionized by mixing in fibres of steel wool; when these are heated by induction coils on a special vehicle, the asphalt will melt and reform, becoming self-mending.

Petroski's goal is to ask how, given the importance of the car to the US economy and mobility, federal and state governments have allowed the country's infrastructure to reach crisis point. But he goes beyond hand wringing. With an engineer's technical knowledge and a historian's eye, he offers a nuanced argument about the political, financial and engineering calculus that contributes to failures.

Acknowledging that infrastructure is part of the political domain,

The Road Taken: The History and Future of America's Infrastructure
HENRY PETROSKI
Bloomsbury: 2016.

The heavily used I-35W bridge in Minneapolis, Minnesota, collapsed in 2007.

Petroski urges political engagement. He cites the controversial rebuilding of the eastern span of the Bay Bridge in Oakland, California, which opened in 2013. This cost a whopping US\$6.4 billion, took 12 years to build, was beset by construction problems and was arguably over-designed. He also discusses the disputes over the Department of Transportation's Highway Trust Fund, intended as the primary support for federal investment in US road systems, but due to run out of money this June. Politicians, he shows, too often choose expedience over sound solutions.

Despite that focus, Petroski does leave out many of today's crucial political debates. There is almost no discussion of the local decisions that shape US roads, such as where or how state and city officials decide to apply federal and state funds, or how municipalities shore up their road funds through different financing mechanisms. Nor does Petroski delve into the vexed issue of the displacements caused by interstate construction since the 1950s, which at its peak forced between 60,000 and 100,000 people to leave their homes every year. Finally, despite framing the book as a look at choices made

and not made, he does not comment on the possibility that roads and their continued construction are creating further problems.

As politicians and citizens consider how to fix existing highways, byways and bridges, they must also consider whether remaining so tethered to the system is a necessity. Might it not be time to ask how major investments in mass transit could complement, if not start to replace, the US reliance on cars? Reflective decision-making is, after all, at the core of what this informative book recommends. ■

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CLARIFICATION

Surfaces, the exhibition reviewed in 'Medical modernist' (*Nature* **530**, 30–31; 2016), was originally a joint production of the Museum of Concrete Art and the German Museum of Medical History, both in Ingolstadt.