



Vast reserves of lithium carbonate salts in Bolivia and elsewhere in South America could sustain vehicle battery manufacture for centuries.

TECHNOLOGY

Charging towards the superbattery

Lithium-ion technology is bringing us closer to solving energy and transport problems, finds **Bruno Scrosati**.

When, in 1801, Alessandro Volta unveiled his 'electric pile' gadget to Napoleon Bonaparte, he could not have imagined that, two centuries later, his invention would be central to human life. His primitive electrical cell of zinc and silver electrodes separated by a brine-soaked felt led to the compact electrochemical power source that dominates modern consumer electronics — the lithium battery.

In *Bottled Lightning*, science journalist Seth Fletcher explains how lithium batteries work and describes the research steps that have led to their ubiquity. The mobile electronics market is booming, producing billions of units a year and billions of dollars in profits. And new challenges for lithium batteries are opening up in green energy. Fletcher describes the fierce competition to develop the next generation of lithium

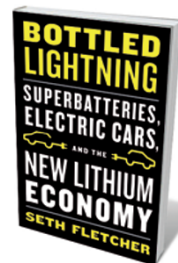
batteries, but could have given more people their due for the existing technology.

Decreasing oil resources and concerns about climate change necessitate greater use of alternative energy sources, such as solar and wind, and the replacement of polluting internal-combustion cars with hybrid vehicles, plug-in hybrid vehicles and, ultimately, fully electric vehicles. As the sun does not always shine and the wind does not blow on command, the success of these renewable sources depends on efficient storage. Electrochemical batteries, lithium ones in particular, are the best option, converting stored chemical energy into electricity

with high efficiency and without toxic emissions.

As yet, lithium batteries do not meet

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Bottled Lightning: Superbatteries, Electric Cars, and the New Lithium Economy
SETH FLETCHER
Hill & Wang: 2011.
272 pp. \$26, £18.99

the technical requirements of hybrid or electric vehicles. The challenge is to move beyond the present chemistry to produce batteries that are safer, cheaper and have greater energy density. This will not be easy. But the ecological, economical and political rewards are so great that many countries are directing tremendous amounts of funding towards research and development in battery technology. The result, as Fletcher puts it, is that in the past decade, "advanced-battery start-ups started popping up like mushrooms after a spring rain".

This intense activity has also given rise to a series of patent conflicts and legal battles over priority, which Fletcher aptly calls "lithium wars". He focuses on the many-sided battle for the patent of the lithium-battery cathode material — a lithium-iron phosphate with an olivine crystal structure that is one of the most promising advanced electrode materials. As he says, such clashes are not new: patent disputes and get-rich-quick hype have dogged the battery business since its inception.

Fortunately, the battery-science community has avoided this bad atmosphere

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and continues to make progress. As well as lithium-iron phosphate, other innovative materials have been used for the three main battery components of anode, cathode and electrolyte. But there is still no lithium battery light enough to power a small electric car over a reasonable distance on a single charge.

Urgently needed are 'superbatteries' with energy densities at least two or three times higher than at present. The most promising candidates are lithium-sulphur and lithium-air batteries, which in principle should be able to store 5–10 times the energy of today's cells. These are conceptually simple, but their implementation has been stalled by a series of apparently insurmountable hurdles: the high solubility of the (polysulphide) discharge products; the high resistance of the electrode materials in the case of lithium sulphur; the slow kinetics of the oxygen electrode; and the instability of the lithium anode in the case of lithium air.

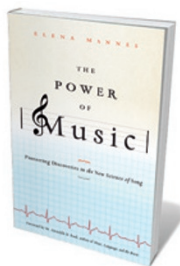
There have been breakthroughs in the past few years with the development of advanced sulphur electrode nanomorphologies, the clarification of the oxygen reduction process, the use of appropriate catalysts for promoting its evolution, and the stabilization of the lithium electrode by covering it with protective films. The road to applications is still long, but the race for the electric car has started. Many car makers are seeking joint ventures with battery manufacturers to pursue the Japanese frontrunners who, having won their early bet on hybrids, are still the major players in electric vehicles.

With demand for lithium set to grow, some question whether Earth's crust contains enough of the metal to sustain its use in vehicles. Fletcher cleverly analyses the debate and gives vivid descriptions of his trips to Bolivia and Chile to visit the two main salt deposits that, together with a third in Argentina, are the richest sources of lithium carbonate. The reserves could last for centuries, so there will be enough lithium to fill up our tanks even in the improbable case of all cars becoming hybrid or electric.

Bottled Lightning is a gripping introduction to this sophisticated technology and its place in our society. My only criticism is that Fletcher fails to credit the group of US and European scientists, including Don W. Murphy, Michel Armand and myself, who in the early 1980s developed the lithium-ion battery concept. The field then fell silent for more than ten years, until the Japanese company Sony optimized the idea for the first commercial lithium-ion battery in the early 1990s. As Fletcher notes, plenty has happened since. ■

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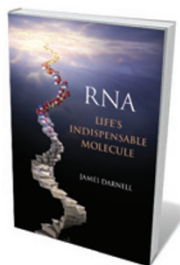
Books in brief



The Power of Music: Pioneering Discoveries in the New Science of Song

Elena Mannes WALKER 288 pp. \$26 (2011)

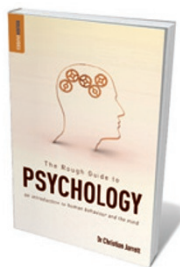
Why does music move us? In a wide-ranging book that spans science and culture, documentary-maker Elena Mannes — who hails from a long line of musicians and patrons, including the builder of New York's Carnegie Hall — describes what the latest cognitive biology and neuroscience tell us about our emotional responses to music. She points to evidence that music can heal, and looks at why music seems to be almost universal across different cultures.



RNA: Life's Indispensable Molecule

James Darnell COLD SPRING HARBOR LABORATORY PRESS 416 pp. \$39 (2011)

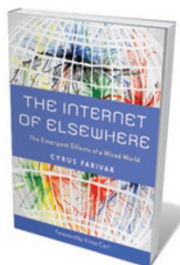
The RNA molecule is crucial for gene expression and protein synthesis. Molecular biologist and RNA expert James Darnell rounds up the latest findings on RNA research in this book aimed at biology graduates. He describes how RNA's varied biochemical and structural properties were discovered, how messenger RNAs are generated and produce proteins, how RNA molecules take on regulatory roles in the cell, and how RNAs might have initiated life on Earth.



The Rough Guide to Psychology: An Introduction to Human Behaviour and the Mind

Christian Jarret ROUGH GUIDES 376 pp. £11.99 (2011)

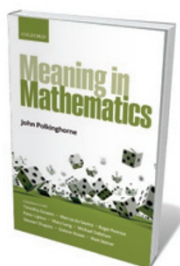
The basics of psychology are outlined in the latest title in the Rough Guide science series. Starting from an individual perspective, journalist Christian Jarret explores the mind and the brain, touching on memory, intelligence and personality. He goes on to analyse our relationships with others, including how we choose our friends and partners. He covers the psychological basis of crime, learning, sport, politics and shopping, as well as conditions of impaired mental health such as depression, anxiety and schizophrenia.



The Internet of Elsewhere: The Emergent Effects of a Wired World

Cyrus Farivar RUTGERS UNIVERSITY PRESS 296 pp. \$25.95 (2011)

Much of the power of the Internet — good and bad — stems from its global reach. Technology journalist and broadcaster Cyrus Farivar profiles web pioneers in four countries — Iran, Estonia, South Korea and Senegal — to illustrate how the Internet is transforming international communications, politics and economics. His case studies examine the Internet's history and effects in these diverse nations, showing that they are at the forefront of developments in Internet phone services, broadband access and digital law.



Meaning in Mathematics

Edited by John Polkinghorne OXFORD UNIVERSITY PRESS 192 pp. £18.99 (2011)

Is mathematics discovered or invented? Nine top scholars, including mathematical physicist Roger Penrose and philosopher Gideon Rosen, muse on whether the discipline is a purely intellectual pursuit or a means of uncovering real aspects of nature. Intended for a broad audience, each essay in this volume — edited by mathematician-turned-theologian John Polkinghorne — is accompanied by comments from the other contributors.