IVAN ALVARADO/REUTERS/CORBIS

Lithium is produced from brine in Chile's Atacama Desert.

INFORMATION THEORY

Knowledge and know-how

Philip Ball examines a study unpicking the broad ramifications of information flows.

The Atacama desert in Chile is the world's biggest single source of lithium. But Chile does not make its own lithium batteries; for that, the metal is exported to countries as distant as South Korea and China. Why?

"Our world is marked by great international differences in countries' ability to crystallize imagination," writes César Hidalgo in *Why Information Grows*: that is, in the ability to turn the inventiveness of the human mind into concrete, saleable products that embody information.

Hidalgo's book is largely concerned with explaining why those differences exist, and what the economic consequences are. In doing so, Hidalgo, a Chilean physicist at the Media Lab of the Massachusetts Institute of Technology in Cambridge, aims to embed his ideas in a broad view of how information economies work both in society and in nature, from Silicon Valley entrepreneurism to genetics.

Information can now be accessed so easily — you can find out about pretty much anything from anywhere, or so it sometimes seems — that it might naively be expected to reduce discrepancies in the local know-how needed to "crystallize imagination". But differences in the character and performance of national economies persist in ways that are not simply the result of inertia; nor can they be explained solely by different labour costs. The core of *Why Information Grows* is about the acquisition (or not) of the capability to put information to use. Many of Chile's recent exports to South Korea were copper (another resource that Chile has in abundance). The reverse trade was largely in vehicles and their parts. The trade balance lies in Chile's favour financially, but Hidalgo points out that this masks a deficit in the flow of embodied information. That does not, of course, mean that Chilean automotive engineers are ignorant. Rather, the know-how to make cars reflects a whole suite of considerations about capacity: a trained workforce, access to materials, distribution channels, reputation, trading partners and so on. To truly understand these macroeconomic transactions, Hidalgo argues, we need to delve into the infrastructure and networks that make knowledge productive and allow know-how to accumulate.

Why Information Grows: The Evolution of Order, from Atoms to Economies
CÉSAR HIDALGO
Basic: 2015

Part of this understanding has already been developed by economists, in particular Ronald Coase, whose 1930s work on transaction costs and the origin and growth of firms won him the 1991 economics Nobel. More recently, social capital — connections, and the trust they engender — has been recognized

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as a key factor in the health of economies. Hidalgo's particular contribution here is to weave these ideas into a theory that provides a conceptual picture of a society's collective accumulation of productive information "in firms and networks of firms". He argues that these entities are not so much the result of that accumulation as the means by which our societies have evolved to make it possible.

What emerges is a new measure of economic complexity that acknowledges not just gross domestic product, but also diversity in the types of product that a nation produces. This index, Hidalgo says, offers a metric that predicts long-term economic growth. His thesis here is dense and not always lucidly explained, but it contains some innovative thinking about what drives growth that could help us to navigate the turbulence of the ever more interconnected global economy.

Hidalgo wants to take his ideas about information and its productive exploitation beyond economics, especially into biology and ecology. In a nutshell, the task is to restore notions of meaning to information theory. The seminal text *The Mathematical Theory of Communication* (Univ. Illinois Press, 1949) by Claude Shannon and Warren Weaver explicitly expunged the idea that information in itself has meaning, as Hidalgo reminds us. But we often persist in thinking otherwise, not least in the delusions that we can do science by mining big data without a guiding theory, or that genomes contain 'instructions' for making an organism.

The distinction between knowledge and know-how, which seems evident enough in economics, can be profitably made in the natural sciences too. A gene sequence is information; know-how refers to the ability to make something from it, and this cannot reside in the information itself. "DNA has no knowhow and cannot unpack itself; it is a slave to the machinery needed to unpack it," says Hidalgo. This seems obvious, but it is worth restating, if only to remind us that this unpacking process (and not further sequencing per se) is now the most important unanswered question in genomics.

Whether all this really justifies Hidalgo's claim to explain "what information is, where it comes from, and why it grows" is another matter. For one thing, with quantum mechanics being reframed as an information theory, it is unclear whether any classical arguments can give the whole picture. But that does not detract from the stimulating new perspectives on offer. Hidalgo has identified a fertile seam, and all his book really needs (apart from some prose-tightening) is for the title to be turned into a question. ■

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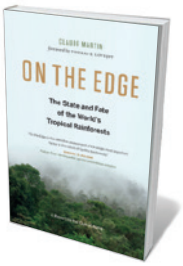
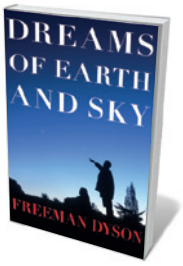
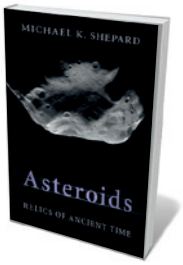
Books in brief



On the Edge: The State and Fate of the World's Tropical Rainforests
Claude Martin GREYSTONE *(2015)*
However crucial in terms of biodiversity, climate moderation and the carbon cycle, rainforests are at bay. Almost one-fifth of the Amazon, for instance, has been lost over 50 years. In this definitive report to think tank the Club of Rome, conservation veteran Claude Martin and contributors cover the territory from the bad old days of error-ridden global forest monitoring to today's smart mapping and strategies for sustainable management. Martin predicts a further 100-million-hectare loss of primary forest by 2050 — but delivers 17 steps for averting the worst. Key reading for environmental policy-makers.

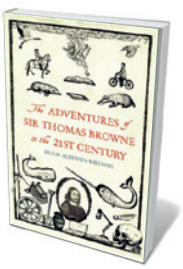


Dreams of Earth and Sky
Freeman Dyson NEW YORK REVIEW BOOKS *(2015)*
"The big blunders in this book are not accidental but intentional." So physicist Freeman Dyson proclaims of the maverick ideas percolating through this collection of his *New York Review of Books* essays and book reviews from 2006 to 2014. Dyson delivers his iconoclasm with humour, honesty and off-the-cuff brilliance, whether riffing off microbiologist Carl Woese's concept of living systems by seeing both thunderstorms and butterflies as "patterns of organization", imagining ecology enriched by genome designers, or mulling over how Mary Shelley's *Frankenstein* cast science as "an agent of doom".



Asteroids: Relics of Ancient Time
Michael K. Shepard CAMBRIDGE UNIVERSITY PRESS *(2015)*
The chunks of broken protoplanet we call asteroids are potential killers as well as scientific gold mines. Both thrills are explored in this comprehensive study of these "little worlds". Planetary geoscientist Michael Shepard recounts the history of asteroid spotting, from pioneers such as Giuseppe Piazzi — who detected the first, Ceres, in 1801 — to today's Catalina Sky Survey, run by the University of Arizona. Interweaving anecdotes from his own work with copious technical detail, Shepard leads us on an expert tour of a fecund branch of astronomy and its lessons for planetary science.

Breathing Space: The Natural and Unnatural History of Air
Mark Everard ZED *(2015)*
The air — all 51 quadrillion cubic kilometres of it — is the biggest ecosystem on Earth, an atmospheric ocean connecting all life. Yet as science writer Mark Everard shows in his original study, the importance of this layered envelope of gases and aerosols is hardly reflected in policy. He argues for reassessment, looking in turn at the nexus of atmosphere, biosphere and human culture, and abuses such as air pollution and climate change. To secure "breathing space", Everard calls for an approach integrating management of the atmosphere with that of other Earth systems.



The Adventures of Sir Thomas Browne in the 21st Century
Hugh Aldersey-Williams GRANTA *(2015)*
A playful erudition permeates this biography of Thomas Browne, the seventeenth-century English polymath who wrote the debunking classic *Pseudodoxia Epidemica*, coined 784 new words and had an eye for patterns in nature. Hugh Aldersey-Williams zips between our time and Browne's, and through the East Anglian landscapes Browne knew, to reveal the man and his work. Browne emerges as an exemplar of synthesized knowledge — and as such, curiously at home in today's cultural remix of science and humanities. **Barbara Kiser**