JAMES KING-HOLMES/SPL

A human femur, thought to be from medieval times, being sampled for carbon dating.

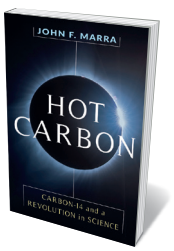
GEOSCIENCE

Radiocarbon revolution

Chris Turney applauds a book on carbon-14 and its key applications.

It is nearly 80 years since the discovery of carbon-14, a radioactive isotope of the sixth element. Because its decay can be used to track the passage of time, radiocarbon has made myriad contributions across the Earth, environmental, biological and archaeological sciences. In the wonderfully engaging *Hot Carbon*, oceanographer John Marra takes this story much further, exploring not just the science, but why we should care about it.

Radiocarbon is scarce in nature, formed in the upper atmosphere through the interaction of cosmic rays with nitrogen. It is rapidly converted to carbon dioxide, and filters into a host of carbon reservoirs in the biosphere and ocean. Living organisms constantly take up ^{14}C, and after they die, the isotope decays at a known rate. By measuring the amount left in a carbon-based sample, it is possible to calculate its age. Since the 1940s, the technique has been used to date materials as much as 60,000 years old, capturing everything from the early migration of modern humans out of Africa, by dating bones and charcoal from ancient hearths, through to the incredibly slow growth rates of mosses living on the fringes of Antarctica. In retelling these facts, Marra offers compelling stories about the great researchers — many long forgotten — whose discoveries made possible the theory, practice and further findings we now take for granted. There's enough to satisfy the most insatiable informavore.



Hot Carbon: Carbon-14 and a Revolution in Science
JOHN F. MARRA
Columbia University Press (2019)

Hot Carbon starts with the extraordinary story of chemist Martin Kamen, born in Canada to Russian immigrants. In February 1940, Kamen was trying to produce a new isotope of carbon at the Berkeley Radiation Laboratory at the University of California. Sleep-deprived after three nights of collecting sufficient irradiated graphite to measure the hoped-for isotope, he stepped outside. His bedraggled appearance caught the attention of police; worse, he fitted the description of an escaped convict who had gone on a murder spree. Hauled to the police station, Kamen was finally released when a survivor of the bloodbath confirmed he was not the suspect. Kamen returned to the laboratory to find that his colleague Sam Ruben had analysed the carefully gathered sample and found that it was measurably radioactive. The story of ^{14}C thus began with a dose of high drama.

Originally expected to have a half-life of just minutes or hours, this heavy form of carbon was considered a low research priority. But Kamen and Ruben's efforts proved that it would be stable over millennia, opening up a breathtaking number of research avenues (its half-life of 5,730 years was determined some years later). Kamen never received the credit he deserved, becoming a victim of the US anti-communist fervour of the 1940s and 1950s. Those who applied his insight, such as chemists Willard Libby and Melvin Calvin, reaped the scientific reward.

We follow the ^{14}C trail through a number of disciplines, learning, for instance, how Calvin and his team used the isotope to trace the way in which plants convert CO_2 into sugar, revealing the intricate processes underpinning photosynthesis. We see how radiocarbon was deployed by labs in Britain, Switzerland and the United States to date the flax used to weave the Turin Shroud (believed by some to be the burial cloth of Jesus) to between 1260 and 1390. Radiocarbon dating has shown that Ötzi — the corpse retrieved from melting alpine ice on the Austrian–Italian border in 1991 — is more than 5,000 years

old. And we discover how candidate drugs, labelled with ^{14}C at specific parts of the molecule, can be followed through phases of the body's metabolism to test the drugs' safety and efficacy. There is so much more. Marra explains, for instance, how, shortly after ^{14}C was discovered, dissolved CO_2 in seawater was used to track the movement of currents in the deep ocean, revealing connections around the planet considered unfathomable before.

Carbon-14 may be the star, but scientists, institutions and happenstance have valuable supporting roles. Take Libby, winner of the 1960 Nobel Prize in Chemistry for his work developing radiocarbon dating. At one point, his team waded into the sewers of Baltimore, Maryland, collecting methane produced from human waste to demonstrate unequivocally that it contained considerably more ^{14}C than did archaeological samples and a precisely dated piece of redwood heartwood.

Marra also reveals, in vivid detail, the difficulties faced by early researchers in acquiring precious samples of plankton, which opened up a new perspective on ocean productivity and, ultimately, carbon sequestration. His own experience in this area illuminates the researchers' pioneering spirit in the face of wild conditions, cramped spaces and sometimes surly ships' captains. The technological limitations were progressively overcome by dogged perseverance and a belief that the work would help them to understand the oceans' potential for incorporating inorganic carbon into organic compounds — still the focus of fierce investigation.

Mysteries remain in the Earth sciences, such as the effectiveness of the carbon cycle and the ramifications of human activity, including our seemingly insatiable hunger for fossil fuels. Importantly, Marra shows how ^{14}C can be used to tease out processes across a range of timescales. He explains why the Southern Ocean is the 'gatekeeper' to the planet's ocean circulation, and how abrupt changes in the formation of deep water and the position of the overlying wind belts can drive dramatic shifts in the carbon cycle. Soberingly, a doubling of atmospheric levels of ^{14}C — arising from mid-twentieth-century nuclear-bomb testing — is preserved as a spike in annually formed natural archives, including tree rings. That marker could be chosen to delineate the start of a new geological epoch: the Anthropocene.

Hot Carbon offers a timely perspective on how mind-bogglingly connected our planet is — and how ^{14}C will continue to be important in helping us to understand what lies ahead. ■

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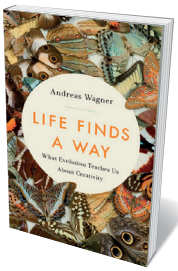
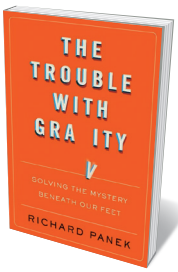
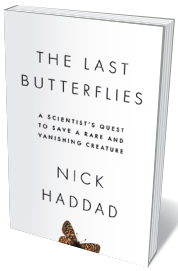
Books in brief



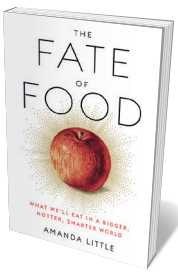
Life Finds a Way
Andreas Wagner BASIC *(2019)*
From gut microbes to elephants, the embodiments of evolution are marvels of innovation. So writes biologist Andreas Wagner, whose eloquent study finds the "augmented" view of Darwinian evolution echoed in the 'landscape thinking' of human creativity — the mental exploration of possibility. Wagner meshes research into areas such as genetic drift with theories on aspects of the creative process (such as serendipity) seen in luminaries from radioimmunoassay inventor Rosalyn Yalow to artist Pablo Picasso, and shows how such a mindset can solve real-world problems.



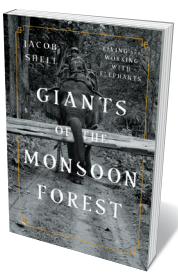
The Trouble with Gravity
Richard Panek HOUGHTON MIFFLIN HARCOURT *(2019)*
Gravity is, scientifically speaking, an enigma. We know that it is a weak force with infinite reach, pulling at matter to form bodies from black holes to galaxies — but that is what it does, not what it is. Science writer Richard Panek follows the evolution of gravitational theories through time, from Aristotle (arguably the first to question why things fall on Earth but heavenly bodies stay aloft) through the momentous discoveries of Galileo Galilei, Isaac Newton and Albert Einstein. He also touches on insights from the likes of poet Dante Alighieri and philosopher-physicist Ernst Mach.



The Last Butterflies
Nick Haddad PRINCETON UNIVERSITY PRESS *(2019)*
Terrestrial ecologist Nick Haddad studies the beleaguered denizens of liminal lands: the world's rarest butterflies. Far from niche research, he argues, findings on species and subspecies such as the St Francis' satyr (*Neonympha mitchellii francisci*) and crystal skipper (*Atrytonopsis quinteri*) offer a valuable lens on the biodiversity crisis. Yet Haddad does not just gather data on habitat loss and other drivers of decline — although he does that with crystalline acuity. He emphasizes that measures such as restoring ecological systems can protect populations of these fragile "ambassadors of nature", against the odds.



The Fate of Food
Amanda Little HARMONY *(2019)*
As Earth's human population tips towards 8 billion, is our food system up to it? In this tour of the brave new world of adaptive production, environmental journalist Amanda Little encounters robot weeders, aquaponics innovators, permaculture farmers, toilet-to-tap water recyclers and other players in the field — both high-tech innovators and eco-traditionalists. That balanced viewpoint extends to broader discussions of debates over genetically modified crops in Kenya and cultured meat production in the United States. Witty, nimble and timely, this is a gem of crack reporting.



Giants of the Monsoon Forest
Jacob Shell W. W. NORTON *(2019)*
In this thought-provoking study, geographer Jacob Shell probes an unusual interspecies alliance: the relationship between people and the working elephants of Indonesia, Myanmar and India. Never selectively bred, the night-roaming pachyderms are essentially wild, yet engage in cognitively demanding tasks such as rescue work during floods. Examining everything from the muscular miracle of the beast's proboscis to the species' wartime work, Shell also charts the threats facing Asian elephants, and the dearth of local voices in relevant policymaking. **Barbara Kiser**