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Book Review

Plants as a force of nature

The Emerald Planet: How Plants Changed Earth's History by David Beerling. Oxford University Press, 2007. $29.95 (307 pages) ISBN 978-0-19-280602-4

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Just how exciting is it to be a scientist? Colleagues and I occasionally talk about whether we would recommend this career to our children in light of the modern pressures on scholarly pursuit and the evaluation thereof [1] – about the hours spent writing and answering emails, applying for grants, serving on committees. But, occasionally, we do get that feeling of being stars in our own movie. A paleobotanical scene: an SUV sweeps down a steep ramp into an active coal pit. The car does a 180 in a cloud of dust. The door opens. Out steps...the paleontologist...tall, handsome/beautiful, hair blowing in the wind (no hard hat needed), revealing a scar from a youthful escapade, dressed in stylish but rugged clothing, hammer in hand, ready. For others, the backdrop might be a laboratory, but the stylish, tall, handsome/beautiful, hair blowing in the wind (from an overhead vent perhaps) image remains the same.

David Beerling wraps some of this romance into a serious science book, *The Emerald Planet: How Plants Changed Earth's History*, which reads like a novel in many places but is constructed solidly on a foundation of diverse scientific literature. The stars are scientists from the past, the present and the near future, pushing back ignorance, racing against each other and sometimes against impending natural threats, some giving their lives, many acutely aware that they are struggling for the superiority of their national intellect over that of others, in a kind of science Olympics. In seven substantive chapters, each an independent short story, Beerling builds a case for the place of plants in the spectrum of natural forces that shape the Earth, particularly the relationship between plants and climate. He starts in the Devonian, with the evolution of leaves driven by changing atmospheric CO_2, takes the reader through a world of high oxygen and giant insects, considers a Permo-Triassic ozone catastrophe allowing the penetration of mutating ultraviolet radiation, examines global warming in the time of the origin of dinosaurs, considers the characteristics of an Earth with warm poles, evaluates the scary effects of greenhouse gasses other than CO_2 during the Eocene and, finally, looks at the potential for positive feedback among plant physiology (C_4 photosynthesis), fires, atmospheric effects and environmental thresholds. The coverage is sweeping.

Many of the chapters present syntheses quite different from those we learned in class or commonly encounter in text books. Take the origin of leaves (chapter 2). Beerling argues that large, planate leaves could not exist in an atmosphere high in CO_2. High levels of this gas suppress the abundance of stomata, thus reducing the ability of a planate surface to stay cool by the transpiration of water vapor to the atmosphere as the leaf is heated by sunlight. Remarkably, the genetic machinery that underlies leaf development is almost the same in all vascular plants – this is true even for lineages that separated in the Early Devonian, long before planate leaves appeared – implying that the potential for leaf formation was there all along. As CO_2 declined during the Devonian, leaves began to appear approximately simultaneously in many different lineages, along with roots. As the author notes, the moment had arrived. Leaves were not the result of some mythical selective pressure from the ether, but rather became a possibility that was not there before: "...it is no coincidence that the evolution of root, shoot, and leaf – the holy trinity of the plant world – took place simultaneously."

Chapter 8 looks at the origin of grasslands, particularly C_4 photosynthetic pathways. Linking low concentrations of atmospheric CO_2 (which suppress recruitment of C_3 plants), fires, smoke, rainfall patterns, plant physiology, and the spread of C_4 grasses, the author synthesizes a wide and diverse range of literature into an interesting and internally consistent argument. He suggests an inexorable positive feedback loop in which the C_4 grasslands burn and the resulting smoke suppresses clouds, thus reducing rainfall and accelerating drought. As such fires burn into C_3 woodlands, already under weakened recruitment, C_4 grasses move into the voids. This contrasts with more conventional explanations that C_4 plants were simply more efficient users of CO_2, especially under water-limiting conditions. Instead, fire is the main driver of their spread. With each chapter, the historical framework for the matter to be discussed is provided. There are copious footnotes where specialists can find the relevant literature, with many substantive elaborations of more technical points, and where the data-to-model intellectual leap is clearly elaborated.

These scenarios must be read with a finger in the chapter-notes section at the back. It is in these substantive notes that one can take in the enormous amount of integration that underlies each chapter. Each story begins with an engaging historical narrative in which science seems to be a fast-paced enterprise, and each includes an integration of plant morphology and physiology, developmental biology, chemistry, and the dynamics of the atmosphere

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and oceans. Most of the chapters present compelling and relatively recent explanatory conceptual models, mainly by Dr. Beerling and his collaborators. Each is presented with an authoritative air that leaves little room for doubt about where the truth of the matter lies. But then, almost every chapter also contains caveats noting the weak points of the argument. Let the reader beware but still enjoy this display of intellectual athleticism.

There is only one chapter in this book that really caused me concern: Chapter 6, 'The flourishing forests of Antarctica'. As with other chapters, this one centers on scientific controversy. Beginning with the Scott expedition to the Antarctic and the fossils the explorers hauled back, the good guys are described as "right-minded scientists", or "inquisitive", whereas the bad guys hold positions that "rest mainly on intuition and 'common sense', not exactly the rigorous criteria demanded of scientific hypotheses." The controversial idea is that of Ralph Chaney [2], who argued that the cost of respiration during long periods of low or no light at high latitudes favored deciduous over evergreen habit. The author asks us how such a hypothesis could survive given that it was based "on nothing more than intuition", and was/is "closer to a religious belief than a scientific theory." However, this hypothesis was hardly built on idle speculation, but on contemporary understanding of plant physiology. Furthermore, we are told that, despite various strands of evidence that "obviously challenge the deciduous view, scientists still refused to abandon their chosen ecological 'religion'". However, a simple check of the notes shows that the offending papers were published before most of the supposedly damning data. It was the author's research team that supposedly delivered the final coup de graĉe to the Chaney model, nearly 60 years after it was proposed, thereby "debunking the myth of the deciduous view" — and well they may have. Yet, ultimately, we are told that "Promising although these initial findings were, we cannot yet claim to have overturned the argument of the deciduous camp." Then what was all this name-calling about?

This story does not describe the flow of events or the motives of the scientists accurately. A more straight-forward, less sensational presentation could have had the same impact. And, as for overturning long-standing explanatory hypotheses – as they say in boxing, you gotta knock out the champ. Science doesn't turn on a dime unless the new data are truly compelling – nor should we expect it to do so, or present it as if it should. The normal activities of scientists certainly should not be incorrectly analogized with religion

The book is envisaged by the author as "a popular science book", and it might indeed have appeal beyond the professional science community. Its main audience will probably be scientists, however, and this would be a good book for a discussion group or a university course. It is provocative, well written, and well researched, and offers an accessible way into the increasingly complex and integrative literature of the Earth's climate system.

References

1 Lawrence, P.A. (2007) The mismeasure of science. *Curr. Biol.* 17, 583–587

2 Chaney, R.W. (1947) Tertiary centers and migration routes. *Ecol. Monogr.* 17, 139–148

0169-5347/$ – see front matter. Published by Elsevier Ltd.
doi:10.1016/j.tree.2007.09.015 Available online xxxxxx.