Echoes of Life: What Fossil Molecules Reveal about Earth History

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mechanisms of colonization and biological invasion in view of a changing climate, readers who direct their attention to only selected chapters would benefit from the inclusion of the specific state of the environment, given the rapid changes in climate in polar regions.

The tables and graphs, and the combination of black-and-white and color images, in this version of *The Biology of Polar Regions* offer a reprieve from the limited black-and-white illustrations in Fogg's original volume. This artwork makes the entire book more accessible and informative.

I did find a number of disturbing typographical and spelling errors (e.g., on p. 14, "12m thick pack ice" should presumably be "1.2m thick pack ice," and the lack of superscripts in table 7.1 is inexcusable). These mistakes detract from the plethora of information contained in the book and may mislead the unwary reader. I also take issue with several statements in the book. The first is in the preface: "Compared with communities of temperate and tropical regions, those in polar habitats are of recent origin and, as a result, relatively simple with few species." This concept is very deceptive. The prokaryotic assemblages in coastal seas, lakes, and subglacial environments are often every bit as diverse as those in temperate and tropical marine and freshwater environments. Moreover, many of these organisms are in the domain Archaea, and arguably not of recent origin. Finally, polar communities are anything but simple, particularly at the microbial level. The complexities imposed on them by bimodal light cycles, continuous low temperatures, and often repeated freeze-thaw cycles lead to intricacy that we may not understand for decades. I also found the following statement in chapter 8 ("Marine Benthos in Polar Regions") to be dubious: "The littoral zone consequently supports no active life in winter." Surely bacteria survive in this environment! This assertion was especially disturbing coming after the emphatic statements in the preface about the ubiquity of the microbial world, especially bacteria and archaea.

The last chapter holds two particularly strong components of this volume: "Further Reading and Web Resources" and the extensive reference list itself. About 20 percent of the almost 600 citations in the reference list were published after 2005, which is commendable, given the historical nature of many of the chapters. The Web sites provide links to most of the major polar research programs as well as to sites on polar conservation and policy. This excellent compilation of references alone makes this book an invaluable source of information.

Moreover, this edition of *The Biology of Polar Regions* packs a plethora of information. The authors' detailed comparisons of Arctic and Antarctic habitats generate a breadth of coverage that few books on polar environments offer. Despite the book's minor idiosyncrasies, it was enjoyable to read, and it's a superb starting point for those in search of information on virtually all topics in polar biology. Like other volumes in Oxford's *Biology of Habitats* series, *The Biology of Polar Regions* should be on the shelf of students studying biological or environmental science, those beginning independent research, and professional biologists embarking on research in a new habitat. Astrobiologists who use life at Earth's poles as an analog for the habitability of other icy worlds also will find this book to be a useful tool.

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Photograph: Steve Hillebrand, USFWS.

MOLECULES, MUD, MOON ROCKS, AND MICROBES

Echoes of Life: What Fossil Molecules Reveal about Earth History. Susan M. Gaines, Geoffrey Eglinton, and Jürgen Rullkötter. Oxford University Press, 2008. 376 pp., illus. $35.00 (ISBN 9780195176193 cloth).

In her first book, *Carbon Dreams* (2001), Susan Gaines combined fact and fiction to depict the life and struggles of a female geochemist as her career developed. The book portrayed the scientific world in both positive and negative ways by highlighting the passion that scientists have for their research, the difficulties and frustrations of finding funding, and the politics of scientific discovery. In her second book, *Echoes of Life,* with coauthors Geoffrey Eglinton and Jürgen Rullkötter, Gaines once again explores the trials and tribulations of scientific discovery, but this time the story is nonfiction, and the real-world context is the inception and growth of biomarker research and geochemistry.

The science of biomarkers evolved while oil exploration was in high gear, the oceans depths were being scoured, and interplanetary dust and moon rocks were a vast mystery. Throughout *Echoes of Life,* the science and the politics of research, as well as the collaborations and rivalries of researchers, are carefully portrayed. For example, the chapter "From the Moon to Mars" recounts how researchers receiving bits of the moon from NASA's Project Apollo—and there were many of them—had to swear to secrecy about their results until 5 January 1970 (the first day of a NASA-convened Lunar Science Conference). The book also discusses the interest of oil companies and government agencies, in the United States and abroad, in funding biomarker research. Given recent negative social, economic, and political attitudes toward fossil fuels and oil companies, readers will be fascinated by the

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historical context of oil research and the quest for the origins of organic matter.

Coauthor Eglinton's observations span five decades, and his work is prominently featured throughout the text. (The preface notes that he had wanted to write a biomarker book for years, so this volume is in part his scientific memoir.) He collaborated with Rullkötter on several projects, and the combination of their scientific perspectives with Gaines's fluid writing makes for an unconventional text on organic geochemistry. The book examines "what molecules (aka biomarkers) know, and what they have to say," as well as how that knowledge came to exist. It has textbook appeal to those in a variety of disciplines—geochemistry, microbiology, and evolutionary biology, for example—but because the science is at times difficult, the book is best suited for students with backgrounds in biology or chemistry. Its major asset is its exploration of the importance of biomarkers to a range of applications, including detecting ancient life forms and signs of extraterrestrial life, reconstructing ancient climates, and studying microbial evolution. Students will learn about the major researchers in geochemistry, their compounds of interest, and the "big picture" regarding their findings, all described in writing that is as vivid as that in a fine novel.

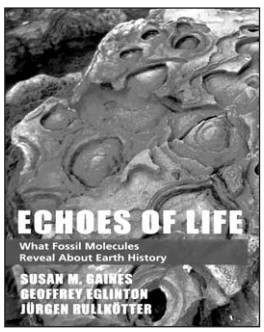
Another of the book's assets is the quality of the illustrations. Deciphering geochemistry jargon can be difficult, even for those with a background in chemistry. *Echoes of Life* incorporates diagrams that explain the concepts in a way that will appeal to a variety of audiences. Graphics from several seminal papers are incorporated and blended with original diagrams to illustrate, among other things, how samples are analyzed (including the use of gas chromatography and mass spectrometry), how the science of biomarker research has changed over the decades, and how the findings have improved our understanding of the origins of organic matter, climate change, and evolution. As a bonus, Geoffrey Eglinton's cartoon musings on all aspects of geochemistry are featured throughout the bibliography.

The first few chapters introduce biomarkers and concentrate on Eglinton's studies as a graduate student and postdoctoral researcher with Melvin Calvin. Calvin had received some of Earth's oldest sedimentary rocks and needed them to be analyzed; Eglinton proved to be an eager colleague. Readers will be drawn in by the description of Calvin and Eglinton's enthusiasm as they study Precambrian exudates and slowly figure out what compounds chromatograph and spectrometer peaks represent, and they will keep reading to discover, or rediscover, some of the primary literature cited throughout the text. For example, the *Science* article (Eglinton et al. 1964) on the identification of hydrocarbons from the Nonesuch shale, a classic that demonstrates the nascence of biomarker research at that time, merits reconsideration. One admires the researchers' ingenuity as they propose and work through connections between pristine and phytane compounds and the digenesis of organic matter in oil.

The importance of analytical instruments and technological innovation in the identification of key biological compounds will not be lost on anyone who has had private conversations with a gas chromatograph or mass spectrometer.

Subsequent chapters highlight how biomarkers have grown in importance to different fields and enhanced the synergies between disciplines. For example, microbes are prominently featured throughout the text. Because of their small size, ancient bacteria and other microbes are not usually found as intact fossils. The chemical remnants of bacterial cell walls and exudates are proving to be strong signatures of the former presence of microorganisms. Coupling this information with molecular analyses, researchers have been able to hypothesize the structure as well as the function of microbial communities.

Biomarker research has also prospered from advances in technology, which in many cases occurred as a result of a particular researcher's desire to isolate one compound. The importance of analytical instruments and technological innovation in the identification of key biological compounds will not be lost on anyone who has had private conversations with a gas chromatograph or mass spectrometer. When they reach the end of the book, readers are likely to have a strong appreciation for the importance of biomarkers, and, like the authors, an optimistic outlook for the science.



The chapter titles are enticing—for example, "From Moon to Mars," "Deep Sea Mud: Biomarker Clues to Climate History," "Microbiologists (Finally) Climb on Board," "Weird Molecules," and "Unlikely Environmental Proxies: Marine Ecology Revisited." "From Moon to Mars" highlights not only the importance of the Apollo 11 mission in the 1960s for moving science forward but also the importance of peer review of claims about the types and origins of organic matter in meteorites and the implications for extraterrestrial life.

To further the current climate debate, the chapter "Deep Sea Mud" explains how compounds such as alkenones, left by the marine alga *Emiliania huxleyi,* among other species, provide a temperature proxy. These compounds allow researchers to investigate differences in temperature in different oceanic regions, and, together with radiometric dating of sediments, allow temperature histories to be constructed. The last few chapters cover everything from evolution to the novel use of biomarkers in anthropological studies; the final one features thoughts about the future of the science.

Those who are interested in geochemistry, and those who are looking to broaden their knowledge of the connections between chemical compounds and the diversity of life, will find *Echoes of Life* well worth reading. Readers will come away with an understanding of what those compounds mean in a given time and place. Although the science Gaines and her coauthors present is sometimes difficult, the book nicely blends chemical structures with the researchers behind the discoveries.

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NOT JUST CARBON BALANCE

Plants at the Margin: Ecological Limits and Climate Change. R. M. M. Crawford. Cambridge University Press, 2008. 494 pp., illus. $72.00 (ISBN 9780521623094 cloth).

Plant carbon balance is a key interest of many modelers and ecologists because of its supposed role in limiting distributions. *Plants at the Margin* shows that carbon balance is not the only limiting factor for plants, and in many cases, not even a significant one. For people like me who never had enough physiology but have nonetheless attempted to model plants and environmental limits, it is a great book.

R. M. M. Crawford, author of *Plants at the Margin* and an emeritus professor at the University of St. Andrews in Scotland, is a specialist in the physiology of plants, especially those in northern and oceanic environments. He is perhaps best known for his work on root respiration and anoxia tolerance, and for his early insights into the physiological effects of climatic warming. *Plants at the Margin* is a scientific synthesis of Crawford's life work, and thus covers a full range of marginal environments. The biological wisdom found in just the first few pages, and the concise way in which it is expounded, is remarkable.

The book comprises four sections: introductory chapters on the essence and biodiversity of marginal areas; two rigorous chapters on physiology and reproduction in marginal situations; six chapters treating particular marginal environments in more detail; and a final chapter called "Man at the Margins," plus a short conclusion.

Habitats are marginal when survival is threatened, so limitation mechanisms should be sought in demography, physiology, and genetics. Plant species are seen as having similar resource requirements and differing mainly in their tolerance to adverse factors. Thus a species' competitive success in good times, when resources are plentiful, matters less to its survival than its ability to utilize and exploit alternative resources in bad times. Crawford offers a good discussion of the significance of carbon balance to both plants and researchers, with recognition that it is the physiology of particular plant organs that may be critical.

In the second chapter, Crawford summarizes various measures of biodiversity, including genetic variation, and contends that variation between habitats (beta diversity) is more suitable for assessing biodiversity than is species richness. Several biodiversity hot spots, as well as dry lands and the Arctic, are described in some detail, with nice examples of remarkable species. This chapter in particular establishes some of the main themes found throughout the book: diversity includes genetic, morphological, and physiological aspects; marginal species often show surprising levels of diversity (which could provide biogenetic resources for restoration efforts); genetically diverse species in refugia may be especially vulnerable to extinction once the stability of the refuge changes; and marginal areas are prone to disruption, and may be stressed even more by global warming.

The second section of the book focuses on resource acquisition and reproduction. An important theme here is that adaptation to one extreme situation is usually maladaptive to others, as illustrated by the opposing strategies a plant needs for the reducing and oxidizing conditions at root surfaces in dry as opposed to flooded situations. The harm to root systems caused by warm periods during winter is very well explained, and discussions on life-history strategies, resource allocation, and shade tolerance are clear and understandable. The treatment of tolerance mechanisms is strong, acknowledging that avoidance strategies, rather than tolerance, obviate the need for specializing adaptations that lead to dependence on particular conditions. Portions of this section describe how some plants find alternative sources of light, water, nutrients, and carbon dioxide, and the summary on mycorrhizae and their significance in nutrient-poor habitats is well done. The reproduction chapter illustrates obstacles in marginal environments at all stages of a plant's development, from flowering to final establishment. Genetic invasion and the high degree of hybridization in marginal areas are well explained, and the degree of invasibility is seen as a result more of resource fluctuations and disturbance than of diversity, productivity, or reproductive rates. Short sections follow on reproduction in particular environments, mast seeding, seed banks, and clonal growth, covering the advantages of asexual reproduction, dioecy, and longevity.

The six case studies go into more detail about the problems of tree lines, a warmer Arctic zone, coastal environments, flooding, woody plants at margins, and high-altitude environments. There is a good history of the tundra-taiga interface, including the idea that grazing by Pleistocene megafauna may have precluded tundra and created a subpolar steppe instead (cf. Zimov's "Pleistocene Park"). Current warming and higher atmospheric carbon diox-

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