How the Earth Turned Green:
A Brief 3.8-Billion-Year History of Plants
by Joseph E Armstrong

reviewed by Marshall D Sundberg

Joseph E Armstrong suggests that How the Earth Turned Green is written for everyone except botanists. As a botanist, I take some exception to that, because, although the book is not laden with all the botanical details about plant structure and evolution that I might want in a textbook for a course exclusively devoted to plants, it provides a salient summary of the important concepts that should guide even a college professor teaching introductory biology. In fact, if you exclude the nearly 140-page appendix, How the Earth Turned Green should be required reading for all pre-service biology teachers and on the bookshelf of all K–16 science instructors. This is despite the author's admonition that “you must realize that books are never, ever going to be able to provide you with the latest information” (page 89).

Armstrong uses plant evolution, in the broad sense, to demonstrate how to teach the big ideas of science underlying the evolution of life on Earth. For instance, in the first half of chapter one, Armstrong introduces taxonomic classification using a personal historical perspective that moves from the three-kingdom system in vogue when he was an undergraduate, through the paradigm shift to a five-kingdom system during his graduate school days, to the three-domain, multiple-kingdom, hierarchy that today leads us to question whether the concept of “kingdom” even makes sense any more. Such a personal narrative is an example of the friendly approach used throughout the book to illustrate important lessons. In this instance, the message is that in science we expect to change our ideas as new information is uncovered and alternative explanations that better fit our ever-growing data pool emerge. As a result, although the underlying purpose of taxonomic systems, to articulate relationships, has not changed since the time of Darwin, the details continue to be illuminated in ever-finer detail as we test predictions based on current understanding.

Deep time is a second major concept Armstrong addresses in the first chapter. Very big (and very small) numbers are difficult for most people to comprehend. Consequently, he is not satisfied with only presenting the typical geologic time line, but rather goes into some detail explaining how an understanding of sedimentary processes enables us to reconstruct geologic history from partial strata exposed in different locations.

Later, in chapter two, Armstrong explains the beauty of phylogenetic hypotheses that allow us to scientifically test predictions about the nature of ancient life “without anyone having been there to observe it”—a frequent complaint of evolution deniers. He does this not just by providing evidence, but also by explaining how the evidence is obtained, analyzed,
and interpreted. One example is how the ratios of carbon-12 and carbon-13 can be used as evidence of early life. Carbon-12 is used preferentially in photosynthesis, with the result that inorganic carbon containing materials, like limestone, produced at the same time will contain a lower amount of this isotope. This skewed isotope ratio provides evidence of life 3.5–3.8 billion years ago. Here and throughout the book, Armstrong never loses an opportunity to champion the nature of science and to debunk misconceptions and outright fallacies propounded by creationists in their attempts to undermine science in general and biological evolution in particular.

The overarching theme of this second chapter is the origin and evolution of metabolic pathways and microorganisms, with a focus on photosynthesis. True to form, Armstrong develops an evolutionary perspective on why these metabolic pathways are not as efficient as might be expected. Why, for instance, do land plants use chlorophyll and not a more efficient “nigerophyll” that would also absorb energy from the middle of the visible spectrum—green light? The answer, of course, is that land plants evolved from aquatic organisms living in an environment with very different spectral qualities. This evolutionary history constrained subsequent innovation when plants made the transition to land. As with many of the pearls of wisdom in this volume, this point is rarely mentioned elsewhere; Armstrong quips, “Good luck finding that idea in biology textbooks...” (page 66).

The third chapter is the last focusing on common evolutionary innovations affecting the breadth of life—multicellularity and the origin of eukaryotic cells. Armstrong begins with an interesting hook to draw in the reader—how should life on Earth be defined? The unexpected answer is “[as] mostly unicellular.” Why is this, you may ask? Because of natural selection, Armstrong answers. Multicellularity arose only when larger size provided a selective advantage—a relatively rare event in the grand scheme of life. Furthermore, as he explains, at the cellular level the single cell of any unicellular organism is more complex than any single cell inhabiting a large cellular organism. The majority of this chapter goes on to explain the endosymbiotic theory of eukaryotic cells’ origin.

The final eight chapters focus on the major evolutionary events characterizing plants in the broad sense. This begins with the vast diversity of marine phytoplankton. One interesting feature, not usually mentioned, is the evidence for successive symbiotic events found in “single” chloroplasts of dinoflagellates. Separate chapters are devoted to the origins of multicellularity in shallow coastal environments and to the environmental challenges, and evolutionary solutions, associated with the transition to the land. One such solution is evident in bryophytes, a relatively little-studied “group” including mosses, hornworts, and liverworts, whose inter-relationships continue to challenge our understanding. The evolutionary solution employed by bryophytes is to essentially avoid the problems as much as possible by staying small and growing in clumps in damp environments.

In other groups, new structures evolved that enabled plants to grow larger and taller on land. These new structures—roots, stems, and leaves—are associated with the vascular plants. As for seeds, which we tend to associate with flowering plants, and perhaps gymnosperms, Armstrong explains them in the context of the plant life cycle and illustrates the diversity of fossil and living plants that possessed variations of this innovation. The evolution of flowering plants, Darwin’s “abominable mystery,” remains a challenge to botanists, as Armstrong describes in the penultimate chapter. In the final chapter, he presents the
development of modern vegetation and the role of humans in the rise of agriculture. The extensive appendix summarizes the salient botanical features of the major groups of plants and our current understanding of their systematic relationships.

In How the Earth Turned Green, Armstrong presents us with a unique approach to the plant kingdom. His refreshing wit and straightforward commentary lead the reader through an evolutionary explanation of why a predominant color of earth is green. His goal is to foster deeper understanding of key concepts, and he raises, and answers, many obvious questions that are almost never asked. As a doctor of botany, I enthusiastically prescribe this book to treat the widespread symptoms of “Plant Blindness.”

ABOUT THE AUTHOR
Marshall D Sundberg is Professor of Botany in the Department of Biological Sciences at Emporia State University. He is best known for his research on the evolution of the maize ear and for student-active learning. He is a Fellow of the Linnean Society of London, the American Association for the Advancement of Science, and the Botanical Society of America and has received teaching awards from the Botanical Society of America and the National Association of Biology Teachers. He teaches introductory biology, honors biology, introductory botany, plant anatomy and physiology, plant kingdom, economic botany, and evolution.

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