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Author: SOLTIS, PAMELA S.

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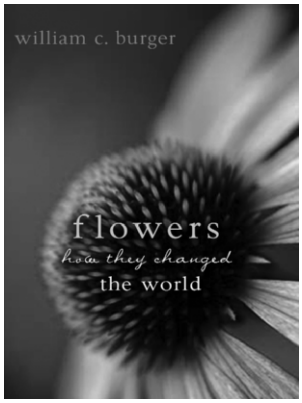
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Plants, Biodiversity, and Climate Change

PAMELA S. SOLTIS



Plants: We depend on them for food, and we surround ourselves with their beauty, but as a society, we generally don't want to be bothered with how photosynthesis works, with how chemical compounds produced by plants serve as important vitamins or antiviral and cancer agents, or, worst of all, with those awful multisyllabic Latin names! Some recent books offer a fresh view: the dual themes of plant evolution and the fundamental role plants have played in shaping the planet. Even my teenage daughters, who claim that plants are boring—as do many college biology students—agree that the books I reviewed for this article present some very engaging ideas. But why is our collective view of plants so negative, when they are so important and appealing? And why is it that we spend so little time teaching and learning about them in our schools? I'll return to these questions later. For now, let me note that these new books require little background knowledge of the topic and can be enjoyed by devoted lay readers.

World-changing organisms

In *Flowers: How They Changed the World,* William C. Burger writes in clear language about the general structure and function of a flower, incorporating colorful descriptions of floral diversity, from the minute, wind-pollinated flowers of oaks, to gaudy orchids and water lilies, to bizarre plants such as the parasitic *Hydnora* (why "bizarre"? see *www.botany.org/Parasitic_Plants/Hydnora_africana.php*). By the end of the first chapter, all readers will be able to identify a compound gynoecium when they see one—and the learning process will have been painless. Reproduction is demystified with a simple and lucid explanation. Subsequent chapters describe pollination and the role of animal pollinators, the friends of plants (and why they are friends), the enemies of plants and how plants defend themselves, and other basic topics in plant science—all in a cheerful, anecdotal style. These pages are peppered with accounts of Burger's own fieldwork, expeditions, and observations, which bring all of this "boring plant stuff" to life.

Perhaps my favorite part of the book is chapter 5, "How Are the Flowering Plants Distinguished?" Although Burger warns that it may be the most "tedious chapter in the book," I think it describes what it's all about: the move of plants onto land, the diversification of land plants (with their concomitant impact on the planet, to be revisited in the discussion below of Beerling's book), and the glorious rise to dominance of the angiosperms (the flowering plants, with nearly 300,000 named species and perhaps an additional 100,000 or more not yet described). Again, Burger captures the essence of the complex fields of paleobotany, molecular systematics, and taxonomy, and makes them accessible to nonspecialists. Armed with this solid background, the reader is prepared to consider the many creative hypotheses Burger presents regarding the importance of flowering plants in the history of the Earth and human culture.

The association between humans and flowering plants is fundamental, as these plants directly or indirectly supply us with most of our food. Indeed, the origins of agriculture transformed human society, and it is the flowering plants—not conifers or ferns—that have this unique relationship with humans. Burger drives this important point home by describing early agriculture in widely separated geographical areas, each yielding its own crops and social customs. He goes even further, exploring the roles that flowering plants may have played in the evolution of primates, culminating, perhaps, in language.

Burger concludes with an epilogue addressing the rapid changes that the human species (perhaps only because of our intricate relationship with flowering plants) is forcing on the planet. After presenting the dramatic, complex history of life on Earth, and the fundamental roles of flowering plants, Burger counsels us to tend our green planet with the same care and intensity that we devote to our own flower gardens.

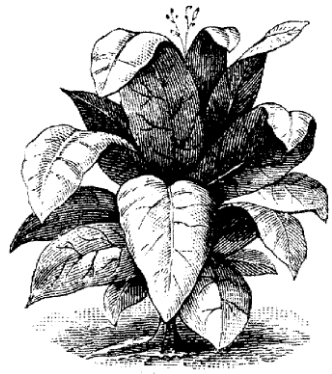
Pamela S. Soltis (e-mail: psoltis@flmnh.ufl.edu) is with the Florida Museum of Natural History at the University of Florida in Gainesville.

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Depth and diversity

The emphasis on flowers continues in the more specialized book *Ecology and Evolution of Flowers,* edited by Lawrence D. Harder and Spencer C. H. Barrett. This comprehensive book is dedicated to the late David G. Lloyd, whose conceptual synthesis laid the foundation for modern plant reproductive biology. After an introductory chapter describing Lloyd's life and contributions, the book is divided into four sections: strategic perspectives on floral biology, the ecological context of floral function and its evolution, mating strategies and sexual systems, and floral diversification.

The chapters draw from an international slate of experts and, like Lloyd's work itself, integrate mathematical theory and empiricism. Although this book is beyond the reach of most nonspecialists, it provides a state-of-the-art view of reproductive biology today, exploring mechanisms and developing the theory behind many of Burger's observations in *Flowers.*



Jonathan Silvertown's *Demons in Eden* explores the processes that lead to and maintain the amazing and bewildering array of plant diversity across the planet. Beginning with the premise that natural selection, if unchecked, will lead to a "super species" or a "Darwinian demon," as Silvertown calls it, this book considers the paradox of the world's tremendous biodiversity in the wake of diversity-reducing natural selection. Silvertown's emphasis is on plant diversity, but the question applies equally to diversity in the other major clades of life, from bacteria to animals and fungi. Charles Darwin plays a central role in the book from the second sentence onward, with his grandfather, the scientist, philosopher, and poet Erasmus Darwin, cast as a supporting actor. Charles's presence is apparent throughout the book, not merely in discussions about natural selection, but also with regard to phylogeny (evolutionary history) and exploration.

Each chapter of Silvertown's book is a field trip, beginning with a guided walk through the Royal Botanic Gardens at Kew, and then on to the Canary Islands, Japan, Panama, Britain, Florida, and Costa Rica. In each tour, we are led to specific observations via theory, interviews with an international cast of botanical scientists, and further discussion. The book is a fascinating voyage, and the reader gets an up-close introduction to science and scientists, not just facts. Having seen the sights Silvertown describes from Kew Gardens (especially the Jodrell Lab), the Canary Islands, the chalk downs, the Everglades, and Costa Rica, I felt camaraderie with the author; all of his readers will appreciate his welcoming style.



Like Burger, Silvertown goes back in time to explore the origin and diversification of flowering plants, and he considers the effects that plants have had on the environment rather than just the reverse. This historical perspective lays the necessary foundation for understanding contemporary observations and for considering the potential outcomes of planetary change.

Silvertown's field trips introduce readers to the many checks that prevent any species from becoming a "demon": soil chemistry, pests, water, wind, and others. The resulting picture is one of complex interactions among species and between plants and their physical environment, with the implicit message that alterations in either biotic or abiotic components of the environment can upset the natural balance and release "demons," thus reducing biodiversity. Examples of "near-demons" or "local demons" throughout the book amply illustrate this narrow balance. Optimism reigns, however, after a field trip to Guanacaste Province in Costa Rica reveals the recovery of natural forest habitat there. The book concludes, as did *Flowers,* with a call for immediate action before it is too late to prevent the demons from being unleashed.

Deep time

In *The Emerald Planet,* David Beerling examines some of the same themes considered by Burger and Silvertown, but on a much deeper time scale—the last half billion years of Earth's history. This time frame begins with the emergence of land plants from their aquatic ancestry and continues to the present. Although plants are usually relegated to wallflower status in most chronicles of the history of life, they take the starring role in Beerling's drama. Plants are typically given credit for making Earth habitable for animals and fungi and for generating an oxygen-rich atmosphere, but Beerling takes this idea further. He recounts the typical tale, but he also offers novel, and perhaps controversial, hypotheses about how plants have modified our planet. Though he echoes Burger's view that flowers have changed the world, Beerling delves much deeper into Earth's chemistry, history, and ultimately climate.

One of Beerling's major themes is the importance of feedbacks, especially involving plants. For example, he suggests that major climate characteristics, such as falling carbon dioxide levels, may have led to the rise of leafy plants and the transformation of Earth's floras, and thus to the transformation of the global climate and terrestrial animals. Likewise, Beerling attributes gigantism in the animal world of 300 million years ago—dragonflies with wingspans of half a meter, centipedes and millipedes a meter long, and scorpions 1.5 meters in length—to high levels of oxygen in the atmosphere, the result of photosynthetic output by vast tropical coal swamps. Other great changes in the history of life are correlated with

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major climatic shifts. Throughout the book, Beerling uses evidence from the plant fossil record (mutant spores, tree stumps from the Arctic and Antarctic, growth rings) to reconstruct past climates and to help explain mass extinctions. Too often this evidence has been disregarded, but Beerling gives it its due, and then some. He makes a final plea for further integration of evidence from the physiology, ecology, development, and genetics of living plants.



Like Burger and Silvertown, Beerling introduces us to the scientists of the past and their contributions to today's hypotheses. His presentations successfully convey the incremental nature of science, demonstrating that new hypotheses often emerge from the combination of observation and syntheses of previous work. He showcases the history of not only botany but also chemistry, physics, math, and paleontology; the major players in all of these fields are fascinating.

Finally, again like Burger and Silvertown, Beerling implores us to consider the effects of our actions on our planet, noting that the uncertainty surrounding dramatic historical episodes of climate change most likely stems from the interactions of effects that have not yet been discovered.

Flowers, Ecology and Evolution of Flowers, *Demons in Eden*, and *The Emerald Planet* all emphasize plant diversity as the product of evolution and as a contributor to our changing planet. The final book that I will highlight, Charlie Jarvis's *Order Out of Chaos: Linnaean Plant Names and Their Types,* looks at how we organize the products of plant diversity into classification systems. At first glance, the connection between this book and the former ones may seem tenuous, but further scrutiny reveals the fundamental link.

Taxonomy, or classification, is one of the oldest sciences in human culture, dating back to preagrarian society, when gatherers distinguished useful plants from harmful ones, and medicinal plants from plants used for food. Over the millennia, classifications have changed as available data, techniques, and philosophies have (see Judd et al. [2007] for a review), but classifications remain as important and relevant to modern science today as they have ever been. Consider that a scientific name is a key to all that is known about a given species: it is our entry into a vast literature on the ecology, evolution, and all other attributes of the species. Biodiversity sciences rely on classifications and the information they contain. Modern classifications of biodiversity start with Carl Linnaeus, the Swedish naturalist and "father of taxonomy" who gave us the binomial system of nomenclature, whereby the species name comprises the genus name and the specific epithet. Before Linnaeus, species names were polynomials, consisting of strings of adjectives sometimes 10 words long. Linnaeus's legacy is the simplification and standardization of nomenclature. His system was first applied in 1753 in *Species Plantarum;* five years later, animal species were similarly renamed in the 10th edition of *Systema Naturae.*

Linnaeus named thousands of plant species on the basis of his own collections, those of his colleagues, and those he received from explorers of other parts of the world. Today's rules of nomenclature state that each valid species name must be associated with an individual specimen—a "type"—that serves as a reference point for that name. Linnaeus's species names lack types, however, because the type concept was not adopted until 150 years after *Species Plantarum* appeared. For the past century, confusion has abounded regarding which specimens or illustrations were the basis for Linnaeus's names. Jarvis and his colleagues have spent the past quarter century matching Linnaeus's names to the appropriate types, a monumental feat and a timely homage to Linnaeus in the tercentenary of his birth.

Prospective readers may wonder, "What's in it for me? I pay no attention to those pesky types, so this is only remotely amusing." Trust me, there is more. In the introductory chapters, the biographical vignettes of Linnaeus, which emphasize the role of chance in his ability to continue his work as a naturalist, reveal the activities of pre-Darwinian botanists. Today, Linnaeus is revered as a national hero in his native Sweden—his face is on postage stamps, hotels and bars are named in his honor, and so forth—and seeing his scientific contributions (both good and bad) in context is well worth the time spent reading the early chapters of the book.

Specialists will be amazed at the nearly 700 pages of plant names and types: *Order Out of Chaos* will long serve as an important reference for plant systematists and for conservationists, which brings me to the connection between this book and the others. Biodiversity cannot be conserved, in any measure, unless we know what it is that we are conserving. In this age, when entire genomes can be sequenced with relative ease, it is unfathomable that perhaps more than 100,000 species of plants remain unknown to science, or that perhaps a quarter of all plant species will be extinct before they are ever described. Basic taxonomy needs our support because it is the foundation of all other endeavors in biology, from ecology to genomics.

The new green revolution



Collectively, these books demonstrate that plants are not bystanders in the history of life: rather, Earth's history, recorded in the paleobotanical record, has been dramatically affected by plant diversity. The wonders of plant diversity stretch beyond our love of gardens to the fundamental relationship that humans have

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with plants—plants are the source of our food, shelter, and medicines, and they are one of the cornerstones of our culture. For these reasons alone, plants are immensely important to the well-being of our species. But, as these books make clear, plant diversity and the health of natural floras are essential for the well-being of the rest of the living world. What can we learn from the past? That massive changes in oxygen and carbon dioxide levels led to substantial changes in life on Earth; that the introduction of a single nonnative species can destroy an ecosystem (see also Simberloff [2004]); that interactions between living organisms and their physical environment are complex, with unexpected outcomes and unexplained subtleties; and, finally, that ecosystems can recover from misuse and disrepair.



Perhaps one of the largest barriers to positive action for conservation or environmental protection is the general public's lack of understanding of the basic role that plants play in modulating our environment. Although the books I reviewed in this article, with the exception of Harder and Barrett's more specialized volume, are accessible to any educated reader, the knowledge gap between the average college-educated American and the readers who would most enjoy these books is still quite large. Unfortunately, plants, in all their diverse glory, are too often omitted from many biology curricula, and nonbiology majors are only rarely introduced to plant biology. Even biology teaching curricula often lack plant components, so teachers may be uncomfortable teaching the plant science section of high school biology courses. Most students consequently enter college with minimal knowledge about plants, and this limited exposure (often repeated in introductory college biology courses) does little to engender enthusiasm for the subject.

I am advocating a "green revolution" of sorts—one that incorporates more plant biology into K–12 and university curricula. Plants are great study organisms for learning about the scientific method (see *www.plantingscience.org*). Science at all levels would benefit from further forays by our younger students into scientific reasoning and critical thinking. Furthermore, learning about flowers, plant diversity, and the environment is wonderful preparation for careers in agriculture, including emerging opportunities in the development of biofuels. Most important, knowledge of basic plant science will lead to a more informed public, one that can better understand environmental issues and make choices—both personal and professional—based on science, not ideology.

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