Book Reviews

Avenues for Plants

The Evolutionary Biology of Plants. KARL J. NIKLAS. University of Chicago Press, Chicago, 1997. xx, 449 pp., illus. $65 or £51.95, ISBN 0-226-58082-2; paper, $19.95 or £15.95, ISBN 0-226-58083-0.

"Convergent evolution between representative species of the New World plant family Cactaceae [left] and the Old World plant family Euphorbiaceae [right]. Arborescent, broad-leafed species found in tropical regions [top] are believed to reflect the ancestral condition. Small species with succulent, short, and sparsely branched stems [bottom] are highly derived and adapted to arid desert conditions." Species such as those shown in the middle "can be arranged into a morphological transformation series purported to show the reduction in leaf size, woody stem tissues, branching and overall plant size attending the radiation . . . into arid environments. Detailed phyletic and comparative morphological analyses are required to determine the precise ancestor-descendant relations among these species and to determine whether this is an example of convergent or parallel evolution." [From *The Evolutionary Biology of Plants*]

Covering a topic as broad as the evolutionary biology of plants is a daunting task. A number of authors have attempted to do this, often in the broader context of the evolutionary biology of all organisms; others have concentrated on the present, focusing on issues of population biology, mating systems, and reproductive isolation of populations. What sets *The Evolutionary Biology of Plants* apart, and ultimately makes it compelling and of broad interest to all evolutionary biologists, is its emphasis on the past (the fossil record) and an underlying theme that basic aspects of evolution were likely dictated by fundamental chemical and physical laws. Thus the author, a renowned paleobotanist, plays to his strengths, a goal he clearly states in the introduction.

The strongest portions of the book are parts 2 and 3, entitled, respectively, Life's Chronicles: The Fossil Record and Adaptive Walks: A Hypothesis. These two sections are, of themselves, reason enough to read this book; they will appeal to both beginning and experienced evolutionary biologists. They are sandwiched between a review of evolutionary basics and a final section dealing with long-term evolutionary trends. The overview of evolutionary basics is solid; particularly strong is the review of the classical literature on such topics as hybridization, speciation, and polyploidy. The discussion of long-term trends is a novel mix of topics that encompasses morphological divergence and convergence as well as tempos and patterns of molecular and morphological evolution. I personally found most interesting the detailed accounts of the remarkable convergences of the early vascular plants calamites and lepidodendrids, which independently evolved an arborescent growth habit (reaching heights similar to those of many extant trees), wood, leaves, heterospory, and cone-like reproductive structures.

In Life's Chronicles, Niklas provides an excellent, easy-to-read summary of the origin and early history of life; the treatment of the origin of photosynthesis is particularly insightful, as is the presentation of the endosymbiotic origin of plastids and mitochondria. Niklas stresses the reticulate nature of the tree of life—that is, that the evolution of photosynthetic lineages of eukaryotes involves secondary as well as primary endosymbiotic events. The author's paleobotanical background is again manifested in an excellent treatment of the invasion of land by embryophytes, the evolution of vascular tissues, heterospory, and the seed. We learn that recognition of the first vascular plants is not simple or clear-cut; for example, the well-known *Rhynia major*, featured in textbooks for decades as one of the first vascular plants, may not be a vascular plant. The evolution of the ovule and the experimentation and innovation that occurred among ancient gymnosperms are all nicely reviewed.

There are a number of ways to visualize adaptive evolution. Niklas develops an approach first proposed by Sewall Wright in which evolution is viewed as a "walk" over a fitness "landscape." Niklas embarks on a series of computer-simulated "adaptive walks" on fitness landscapes; these walks constitute, in my estimation, the strongest, most thought-provoking part of the book. This approach provides a new and important perspective on evolution, elucidating why the evolution of several major plant lineages may have occurred as it did. The basic theme of this portion of the book is that physical and chemical laws limit the number of morphological and anatomical options that are theoretically available to plants. Only a very few of the enormous number of possible options actually work; as the author states, "the rest are mere junk." That is, the computer-simulated "walks through design space" are essentially forced to move along certain pathways that are "dictated by chemical and physical laws."

As an example, the author conducts an adaptive walk through an aquatic landscape to examine the relationship between cell surface area and volume. This walk through cell morphospace identifies the same sequence of cell geometries observed for progressively larger unicellular plant species (sphere → oblate spheroid → prolate spheroid → cylinder); that is, this adaptive walk for hypothetical cells mimics the real-life relationship between cell surface area and volume for both real bacteria and unicellular plants. As Niklas notes, this may simply be fortuitous, or it could mean that cell geometry and shape have been adaptively varied to achieve the maximum surface area for any given volume.

Adaptive walks concentrating on the terrestrial landscape reveal the underlying importance of basic engineering principles in stem anatomy. The first vascular plants had vascular tissue confined to the center of the stem; for these small plants, this is sound engineering. But for larger vascular plants, movement of support tissue to areas closer to the outer stem surface is needed from an engineering standpoint, just as is required in tall buildings. Beginning with early vascular plants, Niklas models walks for three individual biological tasks (light harvesting, mechanical stability, and reproduction), for pairs of these tasks, and for all three simultaneously. Not only are the phenotypes occupying adaptive peaks and the predicted morphological transformations largely compatible with those actually observed in the fossil record, these adaptive walks show that organic complexity may not impose the severe limitations on evolution sometimes envisioned; indeed, the reverse may be true: the evolution of more complex organisms "may lessen the burden of climbing the adaptive peaks of a fitness landscape" by converting one or a few sharp peaks into a "gently rolling plain." Other adaptive walks on the terrestrial landscape suggest that aerodynamic principles governing wind pollination played a major role in the early history of seed plant evolution.

Clearly, evolutionary biologists from different backgrounds could point to numerous possible topics that could have also been included in a text with such a broad title as this one. A population biologist, for example, would expect a very different text with this title. Instead, Niklas has produced an intriguing mix of basic evolutionary biology and stimulating insights via his adaptive walks into the architectural, chemical, and physical constraints that may have played a major role in plant evolution.

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Programs in Physics

Conceptual Developments of 20th Century Field Theories. TIAN YU CAO. Cambridge University Press, New York, 1996. xx, 433 pp. $59.95 or £45. ISBN 0-521-43178-6.

Since the 1960s quantum field theory not only has been at the center of developments in the physics of fundamental particles, it has also made important contributions to condensed-matter physics and even to cosmology. Cao's book tells the story of how all this came about and advises us on how to think about it too. It is an unusual book—neither a textbook nor a history nor an interpretative essay. Rather, the book integrates historical scholarship with solid scientific exposition and puts them both to work in clarifying the central concepts of field theory and their transformations. It is immensely successful at this. Building on that success Cao proposes an account of scientific change as what he calls "ontological synthesis," an account that constitutes a structural kind of scientific realism.

Cao begins with 19th-century developments relating to the electromagnetic field, which is the background for the three 20th-century field theory programs around which his story unfolds. The first of these is the geometric program (where space-time itself becomes a dynamical object) associated with Einstein's general theory of relativity and its successors. He then moves to the quantum field theory program (roughly 1927–1950) centered first around quantum electrodynamics and later including other fields like that of the neutrino and meson. This part of the book begins an interesting discussion of the so-called anomalies and of various technical problems concerning "infinities" and renormalization. Several of these difficulties, including problems with renormalization, led to a serious impasse for quantum field theory, which was overcome by the third of Cao's programs, the gauge field program. This program incorporates the renormalization group and, with quarks and all, characterizes the "standard model" of particle interactions, providing a unification of weak and electromagnetic forces. Cao stops his story with a discussion of effective field theories, a tower of gauge theories each keyed to interactions at different ranges of energy. He mentions superstring theory and other visionary programs for grand unification ("theories of everything") only in passing.

The book is studded with gems. One is the treatment of the development of general relativity (pp. 65–82). Here Cao navigates expertly among the conceptual difficulties that confronted Einstein and sometimes led him astray: the physical significance of general covariance, Mach's principle, and the so-called "hole argument." These few pages ought to be required reading for every student of relativity, certainly for every teacher of the subject.

Cao regards each of his three programs as a progressive development-and-transformation of the classical electromagnetic field. For Cao the comparability of these different field-theoretic conceptions does not depend on there being common physical entities to which the programs are committed (the specific fields or particles he associates with each program); rather, comparability derives from certain abstract, structural constraints that the programs share. These include very general constraints (such as gauge invariance or quantization) and more local ones like the requirement that field-like entities be superimposable and that they lack individuality. This "structural realism" has a long history in the literature on science, and a history of problems too. Since different discourses always display significant structural similarities *and* differences, can we rely on judgments pointing to just one (comparability) or the other (incomparability) as pointing objectively to what is really real? Cao does not resolve such difficulties with structural realism—nor has anyone else.

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Browsings

AURA and Its National Observatories. Frank K. Edmondson. Cambridge University Press, New York, 1997. xviii, 367 pp., illus. $80 or £65. ISBN 0-521-55345-8.

An account of the Association of Universities for Research in Astronomy and its role in the establishment and management of the Kitt Peak, Cerro Tololo, and other U.S. observatories and the Space Telescope Science Institute, as seen by a participant in the events.

Boundaries and Barriers. On the Limits to Scientific Knowledge. John L. Casti and Anders Karlqvist, Eds. Addison-Wesley, Reading, MA, 1997. x, 262 pp., illus. $39.95. ISBN 0-201-55570-0.

Ten papers in which John Barrow, James Hartle, Piet Hut, Harold Morowitz, Robert Rosen, Karl Svovil, Joseph Traub, and others consider whether there are questions in physics, biology, or economics that science can never answer—"the logical, not the practical, limits of scientific knowledge."

Life on Mars? The Case for a Cosmic Heritage. Fred Hoyle and Chandra Wickramasinghe. Clinical Press, Redlands, Bristol, UK, 1997. x, 222 pp., illus., + plates. £17.50. ISBN 1-85457-041-2.

Two astronomers who have long advocated the view that life on Earth has extraterrestrial sources consider recent evidence they believe supports that view, seeing an incipient "paradigm shift" owing to recent evidence from comets and meteorites and offering reflections on extraterrestrial sources for human illnesses and biological evolutionary changes.