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Developmental & Structural

Plant Physics

Karl J. Niklas and Hanns-Christof Spatz.
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I teach a second-year course on plant form and function as though it were an architecture class. If instead I were ever to teach a fourth-year course on plant form, function, and also the environment, it would be as a physics course, with Niklas and Spatz's brilliant new book *Plant Physics* as the text. This is truly a lovely book, with all the remarkable idiosyncrasies that we have grown to expect from the whimsical, quixotic genius of Karl Niklas (sorry, but I don't know Hanns-Christof Spatz's work very well, although probably should learn it).

The material in this book is very good and exceptionally nuanced. For instance, the authors do not make a mockery of adaptation. They truly understand and care about tradeoffs and multi-level selection. For their first simple example, they examine the basic equation for photosynthesis, highlighting its two inputs—carbon dioxide and water. For aquatic plants, water is easy to come by, but carbon dioxide is not. By contrast, for terrestrial plants, carbon dioxide is easy to come by, but water is lost. Niklas and Spatz go directly to fundamental constraints and never let readers forget them, which is fantastic.

But this is not a book for the novice or faint of heart. While advertised as a book that allows mathematicians, physicists, engineers, or botanists entrée into the other three fields, you probably need expertise in all four fields to fully appreciate this book. The first two chapters are introductory, providing essentials of botany and physics, respectively. Although elegantly written, one would be hard-pressed to use these as a primer. For instance, what physicist will really understand that cork cambia can arise from epidermis, cortex, or primary phloem? This probably seems even more confusing to an outsider who might read the text to imply that vascular cambia cannot arise from cortex (or pith or medullary rays), which of course they can in anomalous secondary growth. Likewise, what botanist will want to jump straight into differential equations for transport (e.g., simple diffusion equations) unless they have previously studied fluid dynamics?

That said, the authors do their best to make plant physics as accessible as possible to botanists, who are typically not known for our mathematical acumen. This book does not start with a huge rich theoretical development of the necessary physics (except for the material on physics of solids), but instead pulls many formulae off the shelf as needed. Rather than belabor each equation, the authors are brief in their exposition, but provide just enough detail and caveats that, if you are really interested, you can find out more elsewhere.

This book is at its best when integrating or at least interleaving botany and physics. However, Chapter 4 and the first two thirds of Chapter 5 form an 80-page introduction to the physics of solids. Only in the final 20 pages of Chapter 5 do the authors show applications to plants. Even those applications, though, can be almost completely encapsulated by a single line from the Ani DiFranco song "Buildings and Bridges" (1994), in which she states, "All that steel and stone are no match for the air, my friend; what doesn't bend breaks." To be fair, Niklas and Spatz also use a modicum of applications of physics of solids in Chapter 8 (and I am clearly not cut out to be a mechanical engineer). By contrast, Chapter 6 on fluid dynamics, where the fluid could be either liquid or gas, fully integrates botany. The authors start the chapter discussing different Reynolds numbers during the life cycle of an individual kelp plant: from a very small Reynolds number when the zygote is affixed to a rock in the boundary layer to a very large Reynolds number when the mature kelp plant is many times longer than the waves buffeting it are tall. The authors end the chapter with a discussion of how pollen and seeds fly on the winds.

Chapter 8 is a potpourri of interesting ideas and something of a synthesis, which—as an added bonus—is full of great botanical factoids, such as that chloroplast cell membranes are composed mostly of glycosylglycerides (in lieu of phospholipids) and that plant egg and sperm lack cell walls.

The book ends with a pair of toolboxes, one experimental and one theoretical. The theoretical chapter starts with a gorgeous description (on p. 355) of how best to do biological modeling or any form of hypothesis formation:

In one respect, the only good model is one that fails the test of reality, because a model that gives the right answers can do so for the wrong reasons, whereas a model that yields predictions that conflict with reality immediately requires us to evaluate our assumptions about how reality works. Good models allow us to reject our preconceptions; poor models delude us into believing we have identified causalities correctly.

In fact, that makes for a fine description of science. This book has some quaintness and miscues. The authors refer to dicots, in lieu of eudicots (and magnoliids and basal angiosperms?). The publisher chose a typeface in which zeros look like the lowercase letter "O" and ones look like the lowercase letter "L," which strains reading of a text that otherwise so seamlessly integrates text and mathematics. There are no epilogues—neither for the book as a whole, for individual chapters, nor even for sections of chapters—which makes for staccato reading. The subject index is rather spartan. There are times where it is clear that the physicist (Spatz) wrote about botany without the botanist (Niklas) having proofed the material. For instance, Box 2.1 refers to leaves of water lilies in the genus *Nelumbo* that are one centimeter long that conduct passive diffusion of carbon dioxide underwater. This statement confuses water lilies with lotuses or confuses *Nymphaea* with *Nelumbo*, both of which have leaves that are 20–80 cm long and that absorb most of their carbon dioxide when above water. But, despite these minor foibles, this is a wonderful and somewhat accessible book (other than maybe Jearl Walker's *The Flying Circus of Physics*, what physics books are accessible?) that fills a long-standing gap

–Root Gorelick, Department of Biology, School of Mathematics and Statistics, and Institute of Interdisciplinary Studies, Carleton University, Ottawa, Ontario, Canada