walls. The second model, branch root emergence, involves many of the same enzymes produced by root cap cells but which now act on the cortical cells through which the branch root grows.

Only one chapter, on plant reproduction, focuses on cell adhesion processes and this was limited primarily to pollen/stigma interactions and pollen tube growth, particularly the latter. This is a complex pathway involving signaling molecules and production of adhesion molecules both by the carpellary tissue and the growing pollen tube and the authors do a good job of summarizing current understanding. I was disappointed, however, that no mention was made of other fusion processes involved with floral development such as postgenital fusion of carpels.

The chapter on vascular cell differentiation seemed out-of-place. Even the authors in their conclusion admit that the processes of vascular differentiation, particularly of tracheary elements, only "associate or implicate cell separation-related events."

I found the two chapters bookending the text to be most interesting. Chapter 2, "Cell wall structure, biosynthesis and assembly," provided a good review of the molecular construction of plant cell walls and included many references to current molecular studies. While providing a useful foundation for all of the following chapters, it was critical for interpreting the final chapter, "The role of polymer cross-linking in intercellular adhesion." The latter was written from an interesting perspective -- that of the role of cell adhesion in food quality and preparation. I was particularly intrigued by the details of the spatial patterning of cross links in the cell wall. I had always assumed that primary walls (except of collenchyma) and middle lamella were more-or-less homogeneous. In fact, cross linkages form a "rip-stop" pattern, particularly in areas of tricellular junctions that provide mechanical strength while permitting formation of new intercellular spaces.

This book fits well within the series of annual plant reviews written for researchers and graduate students in plant biology. While few individuals will want to purchase a personal copy, it belongs in the collection of every research library and the libraries of colleges with a faculty member researching problems involving plant cell-cell interactions.

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The Ecology and Evolution of Ant-Plant Interactions. Rico-Gray, Victor and Paulo S. Oliveira. 2007. ISBN 9780226713472 (cloth US$70.00); ISBN 9780226713489 (paper US$28.00), xiii + 331 pp. University of Chicago Press, 1427 East 60th Street, Chicago, Illinois 60637, USA

Plants are the autotrophic basis of life on Earth, and ants -- in terms of abundance and biomass -- are, in E.O. Wilson's words, "the little things that run the world." Thus it should come as no surprise that the rich variety of interactions between ants and plants continues to captivate botanists and entomologists, ecologists and evolutionary biologists, and keen observers of natural history. For nearly fifty years, ecological and evolutionary approaches to the study and analysis of ant-plant interactions have been framed by Janzen's classic study of the mutualism between ants and acacias (Janzen 1966) and the subsequent elaboration of a general theory of coevolution by John Thompson (1982, 1994). In their new book, *The Ecology and Evolution of Ant-Plant Interactions*, Victor Rico-Gray and Paulo Oliveira provide a comprehensive and readable overview of the hundreds of studies of ant-plant interactions conducted since Janzen (1966) and illustrate clearly how well Thompson's framework for understanding coevolution has supported the field.

After a quick introduction to the evolutionary history of ants and plants, and a brief review of the fossil record of ants, Rico-Gray and Oliveira focus their monograph on the two best-studied types of interactions between ants and plants: antagonistic interactions and mutualistic interactions. In particular, they work within the conceptual framework in which mutualism evolvies from antagonistic interactions, and that places both within the context of relationships between consumers and their resources (Holland et al. 2005). This context serves Rico-Gray and Oliviera well, as they move seamlessly from a consideration of clear antagonistic interactions (leaf-cutting and seed harvesting by ants), through mutualisms as extensions of antagonism (ants as primary and secondary seed dispersers), to pure mutualisms in which plants feed and house ants that in return feed the plants and defend them from herbivores. In between, are the conditional mutualisms, both direct and indirect.

The directly conditional mutualisms are characterized by the broad range of associations found among ants and their host plants, including acacias, *Cecropia*, *Piper*, and *Macaranga*, to name only a few. Some of these ant-plant interactions are very elaborate, and include species-specific domatia and food bodies provided by the plant, which in return is strongly defended by the ants. Others are more general, and revolve around extrafloral nectaries or limited provisioning of food resources. Given the spatial scattering of many ant-plants, the heterogeneous spatial arrangement of ant nests and their foraging strategies, and the opportunistic and facultative nature of most associations between ants and plants, Rico-Gray and Oliveira conclude that species-specific coevolution between particular ants and particular plant species is likely to be the exception rather than the rule. This conclusion is supported by the preponderance of evidence presented in their book.

The indirect mutualisms are perhaps more interesting to community ecologists such as myself who are interested in complex webs of interacting species. These interactions involve plants, phloem-feeding herbivores (primarily hemipterans) or other honeydew-secreting insects (butterfly larvae and some gallmaking wasps), and the ants that tend these herbivores. Here the conditional nature of the net interaction between ants and plants is most evident. Ants that tend hemipterans (for example) increase the latter's abundance and survival rate, and since hemipterans can reduce plant growth and survival, there is the potential for insect-tending ants to indirectly and negatively affect the host plant. But, if the ants also provide protection to the plants, and if that benefit outweighs the negative impact of the herbivores, then the net result will be and indirect positive effect of ants on plants. A further twist is added by plants that bear extrafloral nectaries. In some cases, such nectaries may benefit herbivores by attracting ants to tend them whereas in others extrafloral nectaries are thought to have evolved as a defense against ant-herbivore mutualisms.

The existence of ant-plant mutualisms has suggested some strategies for biological control. Rico-Gray and Oliveira highlight work done by Perfecto (1991) on using ants to control pests in small-scale maize-based agroecosystems in Nicaragua, and by Vandermeer *et al.* (2002) in coffee plantations in Mexico. While these two examples are compelling, neither biological control nor chemical control of pests should be used indiscriminately.

Much remains to be learned about interactions between ants and plants, and in their concluding overview of the field, Rico-Gray and Oliveira highlight a broad range of open questions and research topics. These include additional focus on spatial and temporal variability (moving beyond studies of single species in single populations for short times); better assessment of alternative defense strategies by plants (are the ants really necessary?); stronger quantification of indirect costs and benefits in ant – ant-tended-herbivore -- plant systems; more attention to direct feeding of plants by ants; detailed consideration of the other arthropods in the system and elaboration of networks of interactions; and better use of phylogenetic information. This book should successfully generate many undergraduate projects, masters' theses, and doctoral dissertation topics, and should be on the shelf of any botanist, entomologist, ecology, or evolutionary biologist interested in interactions between the organisms that have built the world and those that run it.

Literature Cited

Holland, J. N., J. H. Ness, A. Boyle, and J. Bronstein. 2005. Mutualisms as consumer resource interactions. Pp. 17-35 *in* P. Barbosa and I. Castellanos, editors. *Ecology of predator-prey interactions*. Oxford University Press, Oxford, UK.

Janzen, D. H. 1966. Coevolution of mutualism between ants and acacias in Central America. *Evolution* 20: 249-275.

Perfecto, I. 1991. Ants (Hymenoptera: Formicidae) as natural control agents of pests in irrigated maize in Nicaragua. *Journal of Economic Entomology* 84: 65-70.

Thompson, J. N. 1982. *Interaction and coevolution*. John Wiley & Sons, New York, New York.

Thompson, J. N. 1994. *The coevolutionary process*. University of Chicago Press, Chicago, Illinois.

Vandermeer, J., I. Perfecto, G. Ibarra Nuñez, S. Philpott, and A. García Ballinas. 2002. Ants (*Azteca* sp.) as potential biological control agents in shade coffee production in Chiapas, Mexico. *Agroforestry Systems* 56: 271-276.

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