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BOOK REVIEW

Sharon E. Kingsland, *A Lab for All Seasons: The Laboratory Revolution in Modern Botany and the Rise of Physiological Plant Ecology*, 2023, New Haven: Yale University Press, ISBN: 9780300267228, 385 pp.

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In this expansive study Sharon Kingsland explores the development of the phytotron and its impact on plant physiology, agriculture, and the emergence of physiological ecology as a scientific specialty. The phytotron, an elaborate laboratory complex centered on a collection of greenhouses and controlled environmental chambers, was the brainchild of the Dutch botanist, Frits Went, who had gained prominence for his early experimental studies on the role of plant hormones on phototropism in oat seedlings. Recruited to the California Institute of Technology by Thomas Hunt Morgan, Went designed the first phytotron with the enthusiastic support of university president Robert Millikan. Millikan coined the term "phytotron" to draw connections with cyclotrons and other exotic instruments associated with big science. For Went, the phytotron promised to be a "weather factory" for precisely controlled physiological experimentation on whole plants. The controlled environmental chambers regulated not only temperature, humidity, and light, but also simulated fog, rain, wind and other environmental factors. The precise control of multiple environmental variables made experiments more rigorous but could also speed up research and make it more efficient. Thus, the phytotron could be thought of as a plant accelerator.

The Caltech phytotron opened in 1949, and during the two decades of its existence it attracted visiting scientists from around the world. Despite its successes in supporting both basic and applied research in plant physiology and agriculture, the laboratory complex was chronically underfunded. Millikan originally planned to operate the facility using philanthropic support, but throughout its existence the phytotron also depended on financial support from the university. Critics accused Went of mismanaging the funds that the university supplied. Perhaps more damaging, Went's aspirations for a research program focused upon the whole organism ran counter

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to the growing emphasis on molecular biology at Caltech under the leadership of George Beadle, who replaced Morgan as chair of the biology department. Faced with these institutional challenges, Went left Caltech to lead the Missouri Botanical Garden. The phytotron continued operation for another decade, but eventually was closed in 1969 and the building was torn down in 1972.

Despite the demise of the Caltech phytotron, similar facilities were constructed both in the United States and elsewhere. This proliferation owed much to Went's energetic encouragement but also to the diverse interests of scientists who had visited or worked at the Caltech facility. As a result, several of the newer phytotrons were larger and more flexible than the original, and often were designed to investigate locally important areas of research. Kingsland very effectively explores the diversity of national contexts within which phytotrons were constructed but also the network of conferences, publications, and collaborations that characterized the expansion of what some participants referred to as "phytotronics." Using case studies of phytotrons constructed at other locations in the United States, France, Australia, Israel, the Soviet Union, and Hungary, Kingsland highlights both the common features and unique characteristics of phytotrons that were designed to meet specific needs of the various locations. Some of the case studies also raise intriguing questions for further research and suggest revising well-accepted interpretations of important historical events. For example, Kingsland describes the central role that phytotrons in Australia and the Philippines played in developing new varieties of rice. In contrast to the overarching goal of the Green Revolution to produce "cosmopolitan" rice varieties that could be grown widely, scientists associated with the phytotrons were interested in better understanding the adaptation of rice varieties to specific local environments. The controlled environment of the phytotron was well-designed for this type of research. Kingsland's observations about phytotrons and the Green Revolution are suggestive, rather than conclusive. She urges historians to conduct further detailed studies of phytotrons, beyond her own and those already published by others, to explore this link between the histories of agriculture and ecology. Similarly, Kingsland argues that studying the phytotrons constructed in the Soviet Union and Hungary calls for a reconsideration of how biology was conducted in communist countries during the Lysenko era. Without necessarily challenging Lysenkoism directly, the carefully controlled experiments conducted in phytotrons on agricultural species undercut Lysenko's claims for inheritance of acquired traits.

The phytotrons were centerpieces for a broader "laboratory movement" that Kingsland claims revolutionized botany and led to the emergence of physiological ecology as a recognizable specialty during the 1960s. The promise of understanding the relationship between the whole organism and the environment was the foundation for Went's early plans for the phytotron, but he also thought more broadly about laboratory design including mobile laboratories that could be driven to field sites in the desert and other isolated locations. These technological innovations accompanied and encouraged a change in vision from earlier attempts to combine physiology and ecology. According to Kingsland, late 19th and early 20th century botanists had attempted to study physiology in the field, but beginning in the early 1960s a deeper synthesis of ecology and physiology developed. For Kingsland, this synthesis included interdisciplinary research combining both laboratory and field studies centered on the whole organism, while at the same time considering multiple levels of biological organization from molecules to ecosystems. By bringing together researchers from many different backgrounds this synthesis was social and cultural, as well as intellectual. It constituted, Kingsland claims, a central scientific activity in physiological ecology, and science more broadly.

Kingsland uses studies of secondary metabolites to illustrate both the promise and challenges of this field-laboratory synthesis as it applies to physiological ecology. Secondary compounds are molecules that are not directly related to plant metabolism, but are produced for defense or, possibly, adaptive response to stress. In the case of allelopathy, substances may be secreted by the roots of one species to inhibit the growth of others. Early studies, including those conducted in phytotrons, identified some of these compounds and demonstrated their inhibitory effects under laboratory conditions. Demonstrating an ecological effect under natural conditions was much more difficult, and the significance of allelopathy was challenged by a number of plant ecologists during the 1960s and 1970s. Understanding allelopathy required a synthesis of laboratory and field techniques derived not only from physiology and ecology, but increasingly from biochemistry, molecular biology, evolutionary biology, and phylogenetic analysis. Similarly, studies to identify the adaptive significance of isoprene and other secondary metabolites emitted by leaves of various species of plants required a multidisciplinary approach that included a wide variety of biological specialties, but also atmospheric sciences. The effects of these emissions occurred not only at the level of the organism, but also communities, ecosystems, and the biosphere.

Historians have recognized the importance of synthesis in specific cases, most notably the modern evolutionary synthesis of Mendelian genetics and Darwinian natural selection. Kingsland acknowledges that plant physiological ecology is largely absent from the history of the modern synthesis because the development of the specialty occurred after the major events associated with the modern synthesis. Nonetheless, she deftly connects later developments in plant physiological ecology with earlier work in experimental taxonomy and other botanical contributions to evolutionary biology. More broadly, she argues that as a central scientific activity, synthesis is social, cultural, and institutional, as well as intellectual. The "laboratory revolution" in botany centered on phytotrons and their offshoots provided the material basis for interdisciplinary research that characterizes plant physiological ecology. One might question Kingsland's strong claim that an organism-based physiological ecology forms the foundation for the rest of ecology. While presenting a well-reasoned argument for this position, she readily admits that much remains for future historians to investigate. Indeed, one of the strengths of this pathbreaking book is the way Kingsland points to interesting questions about the history of plant physiological ecology and its relevance for global ecology. She makes a compelling case that understanding the interactions of plants with the environment is crucial for meeting the challenges of global climate change.