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This Week's Citation Classic

Hepler P K & Wayne R O. Calcium and plant development. *Annu. Rev. Plant Physiol.* **36**:397-439. 1985. [Department of Botany, University of Massachusetts. Amherst. MA]

Evidence that intracellular calcium ions act as mediators of physiological and developmental processes in higher plants is reviewed. The article attempts to integrate the physical/chemical properties of the calcium ion with its numerous activities within the cell, thus providing a rationale for understanding primary aspects of signal transduction. *[The SCI®* indicates that this paper has been cited in more than 405 publications.]

Calcium and Signal Transduction in Plants

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Although calcium had long been known to be essential for plant growth, especially in cross-linking acidic cell wall polysaccharides,[1] it was only in the 1970s that researchers began to realize that it might be involved as a cytoplasmic factor in stimulus/response coupling. Heretofore, research on signal transduction had focused on the possible direct interaction between plant growth regulators and nucleic acid metabolism with little thought to ions and membrane transport activity as carriers of information. Given the extensive involvement of calcium in a variety of physiological (e.g., muscle contraction) and developmental (e.g., fertilization) processes in animal systems it seemed only natural that the ion would have a similar role in plants. Studies from Lionel Jaffe and coworkers had formed a bridge between plant and animal systems and had focused on aspects of calcium currents and transients that seemed vital to early development and cell polarity. The often cited "Jaffe's rules" further provided an experimental framework for studies on the role of calcium in signal transduction.[2]

Against this backdrop, the invitation to prepare a review on calcium in plant development was enthusiastically received. Research was moving briskly, and the time seemed ripe to summarize the topic area. But also we intended to provide a critical analysis and a point of view. While we wanted to instill a sense of excitement that permeated the subject matter, we also felt it was important to alert researchers to pitfalls encountered with commonly used experimental protocols. However, while accepting an invitation is easy, delivering the goods by a deadline is another matter. We accordingly left the task of writing to the last possible moment, knowing that its successful completion would require a total immersion effort.

PKH, a faculty member at the University of Massachusetts, had been ensconced at the Marine Biological Laboratory in Woods Hole during the summer of 1984, while ROW, a graduate student engrossed in the calcium-phytochrome interaction in fern spore germination, was experimenting in Amherst. During the summer ROW had studied papers on the physical/chemical properties of calcium while PKH had examined the physiology of calcium action on plants. We then brought our thoughts together and started writing drafts in early September. Borrowing from sports we referred to the writing of this article as "Power Reviewing." We found an empty classroom with yards of black board and literally spent hours hashing out the many problems. Inevitably it was a classic case of the younger teaching the older how things really worked. It then fell upon the older to smooth out the writing and join the arguments into a readable text, while attempting to maintain the level of energy that had been infused. For both of us it was an exhilarating experience, as we struggled, but then could see the concepts emerge and fall into place. The entire writing, which for us is normally slow and painful, was completed within the month of September, and the manuscript was forwarded to Winslow Briggs, editor of *Annual Review of Plant Physiology,* on schedule, but just barely.

We think the review, by pulling together a loosely knit body of information, synthesized a cohesive and novel argument that is important for understanding stimulus/response coupling in plants. These qualities, together with its projection of excitement, have been appreciated by readers who favored its citation. Both of us have been repeatedly flattered by researchers who have praised the review, finding it easy to read and informative, even several years after publication. However, the subject of signal transduction continues to flourish and thus there are several current reviews that illustrate many new insights, such as the recent article by D. M. Roberts and A. C. Harmon on calcium binding proteins in higher plants.[3]

1. **Bennet-Clark** T **A.** Salt accumulation and mode of action of auxin: a preliminary hypothesis. (Wain R L & Wightman F. eds.) *The chemistry and mode of action of plant growth substances.* New York: Academic Press. 1956. p. 284-91. (Cited 115 times.)
2. **Jaffe L F.** Calcium explosions as triggers of development. Ann. *NYAcad. Sci.* 339:86-101, 1980.
3. **Roberts D M & Harmon A** C. Calcium-moduiated proteins: targets of intracellular calcium signals in higher plants. *Annu. Rev. Plant Physiol.* 43:375-414. 1992.

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