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Introduction: signaling in plants

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The development of plants is like that of other organisms genetically determined. However, it is modulated to a remarkable extent by environmental factors, which allows initiation of specific adaptation, competition, protection and defense programs facilitating the sessile life forms of plants. Manifestation of the genetic program requires recognition of internal signals, cellular and systemic signaling, including generation and perception of systemic signals by source and target cells, respectively. Environmental modulation of developmental programs, in addition, requires perception of external abiotic and biotic signals, but also generation of cellular and systemic plant signals that in both cases finally lead to altered gene expression patterns (fig. 1).

Two articles in this multi-author review describe the perception of abiotic and biotic signals via highly specialized receptors. Light perception by phytochromes and the blue light receptor, as well as subsequent signaling events, are summarized and updated by Alfred Batschauer. Similar signaling elements are employed in the transduction of structurally diverse pathogen recognition signals, so-called elicitors, which are perceived by receptors either at the plasma membrane or within the plant cell. The chapter by Thorsten Nürnberger reviews the mechanisms involved in pathogen recognition and intracellular signal generation.

Changes in intracellular calcium concentrations appear to be important for light and pathogen signaling, as

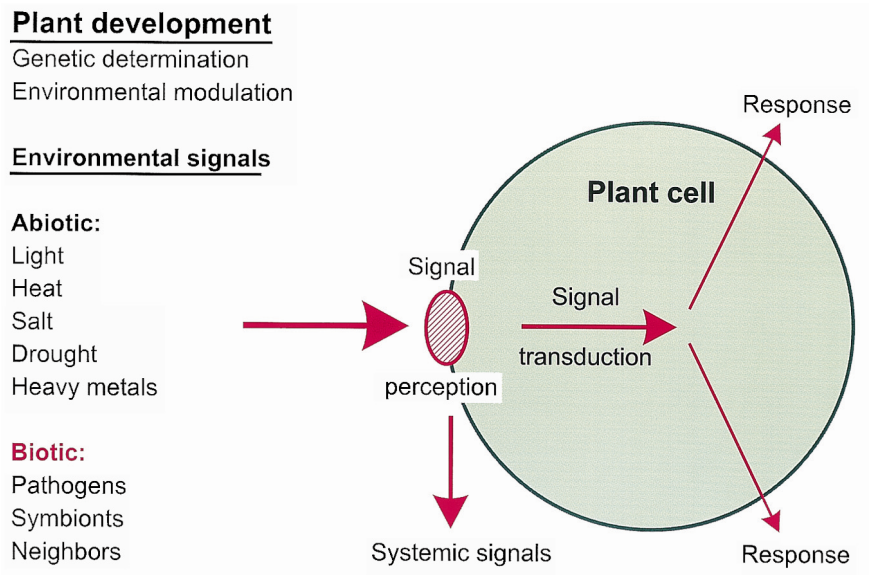

Figure 1. Signal elements in plant development and its environmental modulation.

well as for many other signal transduction pathways in plants. Therefore, the problem of how specificity is generated is a central question to be answered. Jason Rudd and Veronica Franklin-Tong describe not only the progress made in this field together with some important methodological advances, but also how signal specificity may be achieved.

Plant ion channels are not only involved in generating such changes in cellular calcium levels, but on the other hand may themselves be regulated by calcium. As nicely described in the chapter by Sabine Zimmermann, Thomas Ehrhardt, Gunnar Plesch and Bernd Müller-Röber, rapid activation of ion channels is involved in many developmental and environmental signaling and response processes.

Until recently, two classes of signaling elements well established for animal and human systems, GTP-binding proteins and mitogen-activated protein kinases (MAP kinases), were not similarly accepted for plants. Now, MAP kinase cascades have been found to be involved in transducing many external signals in plants cells, as reviewed by Claudia Jonak, Wilco Ligterink and Heribert Hirt. A picture of similar complexity will probably be true for GTP-binding proteins as extensively covered by Friedrich Bischoff, Arthur Molendijk, Chadalavada Rajendrakumar and Klaus Palme. Instead of trying to be exhaustive, this multi-author review tries to highlight aspects of plant signal transduction that are most rapidly developing. Slight overlaps between chapters nicely demonstrate functional links.