Preface

The spontaneous formation of lipid-bounded compartments is one of the preconditions for the genesis of the earliest living cells. Such membranous structures retain essential components, serve as a barrier to intrusion of external contaminants, and, via differential diffusion of ions, generate transient electrochemical gradients that can energize selective exchange processes. In plant cells, the outer barrier plasmalemma, or plasma membrane, is a highly elaborated structure that functions as the point of exchange with adjoining cells, cell walls, and the external environment. Transactions at the plasma membrane include uptake of water and essential mineral nutrients, gas exchange, movement of metabolites, transport and perception of signaling molecules, and initial responses to external biota. Central to all of these processes is the formation of a chemiosmotic gradient across the plasma membrane that results from ATP-driven proton extrusion. This gradient generates a net negative charge on the inner surface of the membrane and a delta pH of 1.5–2. Selective channels and carriers harness this electromotive force to control the rates and direction of movement of small molecules across the membrane barrier and manipulate the turgor that maintains plant form and drives plant cell expansion. Where required, ATP-dependent transporters mobilize the movement of essential molecules against the gradient.

However, it is erroneous to view the plasma membrane as just a diffusion barrier studded with transport proteins. Like other cellular membranes, the plasma membrane provides an environment in which molecular and macromolecular interactions can occur more efficiently. This is primarily a result of the enhanced efficiency of diffusional interactions taking place in two dimensions, the clustering of proteins in oligomeric complexes via protein–protein or protein–lipid interactions for more efficient retention of biosynthetic intermediates, and the anchoring of protein complexes to enhance regulatory interactions. Coupling of signal perception at the membrane surface with intracellular second messengers also necessarily involves transduction across the plasma membrane. Finally, the generation and ordering of the external cell walls involve processes mediated at the plant cell surface by the plasma membrane.

This volume is divided into three parts. Part I, consisting of five chapters, describes the basic mechanisms that regulate all plasma membrane functions. Chapter “Lipids of the Plant Plasma Membrane” by Furt et al. describes the most fundamental aspect of the plasma membrane – its lipid composition and the ordering of membrane lipids into leaflets and domains. The chapter “Plasma Membrane Protein Trafficking” by Peer describes the mechanisms by which proteins are trafficked to and from the plasma membrane. The chapter “The Plasma Membrane and the Cell Wall” by Sampathkumar et al. describes the role of the plasma membrane in cell wall production as well as the interactions between the plasma membrane surface and the cell walls during development. The chapter “Plasmodesmata and non-cell autonomous signaling in plants” by Lee et al. describes the plasmodesmal structures that provide unique regulated conduits that can partially bridge cell wall barriers to provide direct intercellular interactions. The chapter “Post-translational Modifications of Plasma Membrane Proteins and Their Implications for Plant Growth and Development” by Luschnig and Seifert details the regulatory posttranslational modifications made to many plasma membrane proteins.

Part II describes plasma membrane transport activity. Chapter “Functional Classification of Plant Plasma Membrane Transporters” by Schulz provides an overview of the structure and classification of plasma membrane transporters and uses structural characteristics to classify these proteins into groups. In the chapter “Plasma Membrane ATPases” by Palmgren et al., a similar structural analysis is combined with functional analyses derived from experimental results to describe the ATPases that export protons and calcium at the plasma membrane. Chapter “Physiological Roles for the PIP Family of Plant Aquaporins” by Vera-Estrella and Bohnert uses a similar approach to characterize the aquaporin intrinsic membrane protein channels that transport water and other small molecules in and out of the cell. In chapters “The Role of Plasma Membrane Nitrogen Transporters in Nitrogen Acquisition and Utilization” by Tsay and Hsu, “Plant Plasma Membrane and Phosphate Deprivation” by Nussaume et al., “Biology of Plant Potassium Channels” by Hedrich et al., “Mechanism and Evolution of Calcium Transport Across the Plant Plasma Membrane” by Connorton et al., “Sulfate Transport” by Hawkesford, “Metal Transport” by Atkinson, and “Organic Carbon and Nitrogen Transporters” by Tegeder et al., the regulated transport of nitrogen, phosphorus, potassium, calcium, sulfur, metals, and cellular metabolites across the plasma membrane are described. Chapter “ABC Transporters and Their Function at the Plasma Membrane” by Knöller and Murphy returns to a more structural approach to describe what is currently know about the plasma membrane ATP-binding cassette transporters of the ABCB and ABCG subfamilies. The transporter part of the book is rounded out by a description of hormone transport in chapter “Hormone Transport” by Kerr et al.

Part III of the book describes signaling interactions at the plasma membrane, with chapters describing hormone signaling (chapter “Plant Hormone Perception at the Plasma Membrane” by Pandey), light sensing (chapter “Light Sensing at the Plasma Membrane” by Christie et al.), lipid signaling (chapter “The Hall of Fame:

Lipid Signaling in the Plasma Membrane" by Im et al.), abiotic stress responses (chapter "Plasma Membrane and Abiotic Stress" by Barkla and Pantoja), and biotic interactions (chapter "The Role of the Plant Plasma Membrane in Microbial Sensing and Innate Immunity" by Nürnberger and Küfner).

Although these topics have been the subject of many current and past reviews, they are given a unique treatment in this volume, as we have made an effort to concentrate on events and mechanisms that occur at the plasma membrane rather than discuss mechanisms that occur throughout plant cells. It is hoped that this effort will provide the reader with a strong sense of the unique role that the plasma membrane plays in plant physiology and development. Further, the authors of the individual chapters have made an effort to identify areas where there are substantial gaps in our understanding of mechanisms sited on this critical cellular structure. Finally, we hope to convince the reader that a more complete knowledge of plasma membrane structure and function is essential to current efforts to increase the sustainability of agricultural production of food, fiber, and fuel crops.

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1 May 2010

Springer

The Plant Plasma Membrane
Murphy, A.S.; Peer, W.; Schulz, B. (Eds.)
2011, XIV, 494 p., Hardcover
ISBN: 978-3-642-13430-2