Membrane Trafficking: Intracellular Highways and Country Roads

Membrane trafficking, or the flow of membrane material between endomembrane compartments and the plasmalemma, is essential for transport of proteins and other macromolecules to various destinations inside and outside of the cell. Membrane trafficking also underlies the fundamental need for cells to maintain cellular homeostasis, as well as to meet specific demands during signal perception and transduction. The pathways of membrane protein trafficking, starting from the endoplasmic reticulum (ER), are long, branched, and occasionally even bidirectional. The blueprint of the endomembrane system is conserved among eukaryotes and comprises the ER, the Golgi apparatus, endosomes, and lytic compartments. The plant endomembrane system is apparently considerably more complex than in unicellular yeasts; the highly expanded protein repertoire devoted to the endomembrane system and vesicular processes inferred from plant genomes as well as its divergence from other kingdoms would argue for a system that has evolved to serve cellular strategies that best support the plant cell. The biosynthetic functions in the ER and Golgi are followed by sorting at the Golgi apparatus for antero-trafficking to the cell membrane or to lytic or storage vacuoles and retrograde trafficking back to the ER. Constitutive and signal-regulated endocytosis at the plasmalemma is followed by transport to the lytic vacuole or to the Golgi for sorting and recycling. Voluminous studies have been devoted in past decades to structurally and biochemically characterize the different endomembrane compartments and the processes each undertakes in overall cellular metabolism. Arrival of the post-genomic era, together with development of microscopic and computational tools in the last decade, has resulted in an explosion of studies, some reaffirming classical understanding, others uncovering new insights on the membrane trafficking machinery in plant cells as well as the cellular processes and whole plant-related phenomena that the endomembrane system supports. This Focus Issue is organized to provide both Updates and exciting new research articles on these recent findings and suggest paths to chart the future.

The Updates have been written by small teams of scientists who have impressive track records in their specific fields and they span a broad spectrum of topics central to membrane trafficking. The Staehelin and Kang (2008) Update reviews state-of-the-art, high-resolution capabilities in obtaining structural definitions in three dimensions for individual organelles and, in particular, reconstruction of organelles that are undergoing dynamic changes. This is followed by the Held et al. (2008) Update on the prowess of what combinations of fluorescence-based microscope and live cell imaging can achieve for spatial and functional assignments for specific molecules within the entire endomembrane system. The Rojo and Denecke (2008) and Robinson et al. (2008) Updates examine the most recently defined players in the secretory and endosomal pathways and how these may be used to interpret, reconcile, or extend prior results. These provide good roadmaps, especially for researchers whose work would benefit from a membrane trafficking perspective.

The involvement of a large number of regulatory molecules is discussed in the Updates on the small regulatory RAB and ARF GTPases by Nielsen et al. (2008), on SNAREs by Bassham and Blatt (2008), and on Rho GTPases by Yalovsky et al. (2008). Studies in these areas have advanced so much in the last few years that these Updates have gone far beyond a catalog of molecules and their potential functions and include vigorous discussions on the cellular, physiological, and developmental events that these molecules regulate, how they themselves are regulated, and how these regulatory pathways may integrate in the control of vesicular transport.

Several Updates deal with aspects of membrane trafficking from the point of view of a particular physiological process. Kwon et al. (2008) describe recent findings linking plant immunity to secretion pathways depositing compounds helping plants to counteract pathogens. Feraru and Friml (2008) focus on the acquisition of cell polarity by means of controlled deposition of membrane proteins, in particular the PIN auxin carriers. Here, specificity in the sorting of integral membrane proteins is evolving as a future topic of interest. Van Damme et al. (2008) discuss the connections between the cell cycle and membrane trafficking, while Geldner and Robatzek (2008) as well as Aker and de Vries (2008) highlight various aspects, including endocytosis and degradation, of plasma membrane receptors.

A large number of research manuscripts on different biological systems and based on a variety of approaches have been submitted to this Focus Issue. Among the articles in this issue are several studies based on root hairs and pollen tubes, polar growth cell types that are favorite model cell systems for studies in membrane trafficking. Monshausen et al. (2008) and Bove et al. (2008) highlight the use of imaging approaches combined with computational analysis to examine Ca$^{2+}$ regulation of root hair growth and provide spatial definition of exocytic activity in pollen...
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endosome-localized Ca$^{2+}$-ATPase and its contribution
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membrane maintenance in pollen and stigma cells. Esseling-Ozdoba et al. (2008) use synthetic fluorescent
lipophilic vesicles to highlight the role of actin in
establishing the cell plate in Tradescantia stamen hair
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teaching tool and an important resource for research
in the area. Expected next thrusts in the field are to
mine genomics and transcriptomics databases and to
use state-of-the-art proteomics approaches to identify
structural and regulatory components of the endo-
membrane system. Examples of this can be found in
the research report of Kamei et al. (2008) on the
combined use of bioinformatics and functional studies
on PRA1, a membrane trafficking regulatory protein,


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