Plants are composed of 17 essential elements and these must be taken up as nutrients to allow for growth and cell division. Macronutrients are defined by their large amounts in plants (>0.1% of dry mass), while micronutrients are much less abundant (<0.01% of dry mass). C, H and O provide the bulk of biomass but only N, P, K, S, Ca and Mg (in decreasing order of abundance) are considered macronutrients in a strict sense. The micronutrients (Fe, Zn, Cu, Mn, B, Mo, Ni and Cl) are much more heterogeneous with respect to chemistry and biological function: the presence of Ni appears to be required in only one or two processes while the content of Mo is the lowest of the essential nutrients found in a plant. Metals are found in both groups and reflect their multiple catalytic and electron transfer functions in interaction with high and low molecular organic compounds in cells. Hence, the terms metals and nutrients are partially overlapping without precisely characterizing macro- and micronutrients. In addition, so-called beneficial elements are known to promote growth in only some taxa. This term refers to Al, C, Na, Se, and Si, the latter particularly being required by monocotyledonous plants. Other elements are taken up by plants but have no proven function or are even deleterious such as heavy metals.

Much effort has been devoted to study the physiology and biochemistry of metals and nutrients in plants. The aspect of cell biology, however, is an emerging new field, and even a new Gordon Research Conference (Cell Biology of Metals) has been launched recently. While N and S are structural and functional components of proteins, P is crucial for nucleic acids and energy metabolism, Ca, K, Cl, B and the metals are of key importance for a large number of biological reactions. These include photosynthesis, cell pressure, metabolic catalysis, oxygen transport, anabolism and catabolism, redox reactions, cell signalling, etc. Both the regulatory networks and the nutrient aspect of these elements have been successfully investigated using nutrient-deficiency experiments and transcriptome, proteome and metabolome tools as well as targeted approaches. However, much needs to be learnt about nutrient sensing, long-distance communication within the plant and cellular signal transduction chains in response to environmental stress.
With respect to metals, major progress has been made in recent years in our understanding of the biosynthesis of metal-containing prosthetic groups. Complex and multistep biosynthetic pathways were uncovered in greater detail. Progress has also been made in the identification of cellular sites of prosthetic groups’ synthesis. However, our knowledge is scarce with respect to the steps subsequent to biosynthesis. It is largely unknown how these prosthetic groups are allocated, transported and directed to various cellular destinations, ultimately finding their way into the correct cognate proteins. There must be a plethora of transporters, chelators, metal cofactors, protein folding chaperones, metallochaperones, carrier proteins, storage proteins, and insertases involved. Another important objective is to understand how protein trafficking pathways and metal trafficking pathways are integrated and intersect. Further areas of focus are mechanisms of metal ion homeostasis, how cells sense diverse metal ions, how homeostatic mechanisms for different metal ions are integrated at the molecular and cellular level, and how the finely tuned interplay of these components ensures safe transport. Clearly, cellular malfunction, and consequently, disease are the result if any of the various key steps in metals allocation and insertion are perturbed and reduced cell division, growth proliferation and overall performance result from deficiencies of these nutrients.

This book emphasizes the cellular biology of metals and nutrients to provide a new concept that reaches beyond plant nutrition and plasmalemma transport but into cellular physiology. Each chapter contains basic information about uptake, physiological function, deficiency and toxicity syndromes, long-distance communication, and intracellular transport. The chapters are devoted to metals and nutrients where recent progress has been made and highlight the aspects of homeostasis and sensing, signalling, and regulation with cross-references to other organisms including humans. Where gaps are identified in our knowledge, these are pointed out and future research directions envisaged.

October 2009

Rüdiger Hell
Ralf-Rainer Mendel
Cell Biology of Metals and Nutrients
Hell, R.; Mendel, R.-R. (Eds.)
2010, XIV, 306 p. 23 illus., 15 illus. in color., Hardcover
ISBN: 978-3-642-10612-5