Preface

Heavy metals are chemical elements with a specific gravity greater than 5.0. Among the 90 naturally occurring elements, 21 are non-metals, 16 are light metals, and the remaining 53 are (with As included) heavy metals. The definition thus includes the majority of naturally occurring elements, which from a biological perspective is not very helpful. However, only a limited number of heavy metals are soluble under physiological conditions and thus bioavailable to living organisms. Some of these are considered essential for life, including Fe, Co, Mo, Mn, Zn, V, Ni, Cr, Cu, and W. They are required as micronutrients or trace elements because they often act as cofactors in biochemical reactions, but they are toxic when present in excess. Other heavy metals such as Cd, Hg, Ag, Pb, and U have no known biological function and are toxic even at very low concentrations.

Heavy metals are often present as natural components of ultramafic or calamine soils, but the prevalence of heavy metals in the environment has increased more recently as a result of human activity. Metal processing facilities, mines, refuse dumps, sewage sludge, and traffic are all sources of heavy metals. In addition, the intense use of phosphate fertilizers and municipal sewage sludge in agriculture contributes to the accumulation of heavy metals in soils. The increasing concentrations are potentially toxic to both animal and plant life.

Metal mobility in the soil is strongly influenced by root exudates and microbes in the rhizosphere. Mobilized metals bind to root cell walls and are then taken across the plasma membrane by transport systems. Diverse families of metal transporters are induced under metal deficiency conditions, indicating their involvement in the regulation of metal uptake, transport, and distribution in the aerial parts of the plant.

For most plants, both essential and non-essential heavy metals cause toxicity symptoms and growth inhibition when present in excess. Heavy metals induce oxidative stress by generating free radicals and reactive oxygen species; they displace essential ions from proteins and other molecules; and then bind strongly to oxygen, nitrogen and sulfur groups, and hence inactivate enzymes by binding to cysteine residues.

Plants use various strategies to prevent heavy metals accumulating at sensitive sites within the cell, thus avoiding the damaging effects of heavy metal toxicity. One important detoxification strategy is the chelation of metals by a ligand, which is subsequently compartmentalized. Different metal-binding ligands have been recognized in plants and they appear to regulate different stages of metal transport and storage. These include organic acids, amino acids, peptides, and proteins.

Recent advances in molecular biology, sequencing technology, and bioinformatics mainly focusing on model plants, have rapidly increased our understanding of heavy metal detoxification and metal stress tolerance in plants. Understanding the molecular basis of heavy metal tolerance in plants will play a more prevalent role in food safety, and will also provide new strategies to address micronutrient deficiencies through the development of biofortified food crops accumulating higher levels of essential heavy metals such as zinc. Furthermore, to better understand the unique feature of several plant taxa of accumulating exceptional concentrations of heavy metals in aerial tissues will consent to improve the phytoremediation of contaminated sites. The following chapters report a broad overview of plant mechanisms involved in the transport, accumulation, and detoxification of heavy metals and highlight future prospects for the exploitation of heavy metal tolerance in plants.

Verona, April 2012 Antonella Furini