Preface

As sessile organisms, plants have evolved an amazing array of metabolic pathways leading to molecules capable of responding promptly and effectively to stress situations imposed by biotic and abiotic factors. These pathways, often recruited during biological evolution from essential primary metabolism pathways upon initial gene duplication, combine carbon, hydrogen, oxygen, nitrogen, and sulfur into molecules that are capable of herbivore deterrence, tri-trophic signaling (i.e., attracting herbivore predators and parasites), pathogen inhibition, integrating defense responses, UV absorption, quenching of reactive oxygen species, allelopathic activity, attracting pollinators, or seed dispersing animals, heat dissipation, among other activities. Throughout the kingdom Plantae, there are tens of thousands of molecules, frequently restricted to specific taxonomic groups, which play this major role of plant interaction with the environment and are extremely important for plant fitness; these are historically referred to as secondary metabolites, also known as natural products.

In spite of our detailed knowledge of only a fraction of plant secondary metabolic pathways, particularly when considering tropical and subtropical phytodiversity, some major patterns have emerged, revealing a complex regulation of this metabolism. Both constitutive and inducible secondary metabolism activity can be found in different plant species, and frequently an intermediate profile of metabolic activity between these two strategies can be found. A strict spatial and temporal control of gene expression ensures the correct accumulation pattern of various secondary products. Organ-specific, tissue-specific, and cell type-specific expression of different portions of a single metabolic pathway are not uncommon in the biosynthesis of alkaloids and terpenes, for example. The required transport of metabolic intermediates constitutes an additional level of regulation. Within cells, different compartments participate in biosynthetic steps, including chloroplasts, cytoplasm, endoplasmic reticulum, vacuoles, nucleus, and special structures, such as alkaloid vesicles. The induction of secondary metabolism gene expression by wounding, herbivore-derived molecules, pathogen elicitors, and oxidative stress caused by heat, drought, flooding, UV light, or temperature extremes is often mediated by integrating signaling molecules such as salicylic acid, jasmonic acid, and their derivatives. Ontogeny and circadian clock controlled expression are also important features of plant secondary metabolism. At the level of gene expression, the presence of master regulatory transcription factors is a common theme in the metabolism of phenolics, alkaloids, and glucosinolates. These regulators are considered some of the best targets for engineering secondary metabolic pathways.

As can be easily realized, effective engineering of plant secondary metabolism pathways is not a trivial task, mostly due to the various levels of regulation and the often observed close dependence of subcellular, tissue, and organ differentiation for effective expression of metabolic steps. Nonetheless, examples of successful engineering of plants, plant cell cultures, and heterologous expression of plant secondary metabolism genes in microbes are available. The purpose of this book is to provide a source of detailed practical information on some of the most important methods employed in the engineering of plant secondary metabolism pathways and in the acquisition of essential knowledge in performing this activity. Some examples in which the application of these methods has allowed significant advances in the major goal of tailoring plants or microorganisms to become factories of relevant plant secondary metabolites are highlighted. Some emerging strategies for metabolic engineering, still incipiently used in secondary metabolism, are also described, pointing to future directions in the field. The book is intended to be a resourceful reference tool for researchers (molecular biologists, plant physiologists, biochemists, chemical engineers, agronomists) engaged in the challenging task of modifying some of the most intricate products of plant evolution. Hopefully, it will assist scientists' efforts in the goal of sustainably supplying, in a fast changing planet, the ever growing needs of humankind for natural chemicals, such as pharmaceuticals, nutraceuticals, agrochemicals, food and chemical additives, biofuels, and biomass.

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