PREFACE

Living cells possess intricate signaling systems which play crucial roles for sensing and interacting with their environment. The complexity of these systems is exemplified in higher eukaryotes in which physiological functions require coordinated communications between organs at the whole organism level. Understanding these systems is a formidable task and of fundamental importance. Deciphering cell signaling processes requires identification of the actors and resolution of their spatial and temporal dynamics of mutual and coordinated interactions. Although the elucidation of cell signaling mechanisms seems an unresolvable problem as ever more data come to hand, the discovery that nitric oxide (NO) displays signaling function in many, if not all, living organisms is considered as a major breakthrough.

Nitric oxide is a reactive diatomic gas. According to some authors, it may have played an early role during evolution in primitive organisms by neutralizing ozone and by serving as a defence mechanism against reactive oxygen species. Furthermore, the possibility that the release and sensing of NO could represent an intra- and extracellular mechanism before specialized receptors evolved has been proposed. Paradoxically, its involvement as a physiological mediator in mammals was not recognized until the mid-1980s. Nevertheless, over the past 30 years, our understanding of the role of NO in animals has been enriched by fascinating discoveries. First identified as an antimicrobial effector molecule, numerous studies have highlighted that NO is also a unique biological messenger involved in major processes including neuronal signal transmission, blood vessel dilatation and both innate and adaptive immunity. The discovery of the enzyme nitric oxide synthase (NOS) catalysing its synthesis, as well as those of key mechanisms controlling the expression of NOS and mediating NO effects has greatly expanded our understanding of its role. The search for NO functions remains an active area of investigation in mammals with applications in medicine.

From the end of the 1990s, NO was also revealed to be a surprisingly ubiquitous signaling molecule in plants. Indeed, NO possesses an unusually repertoire of physiological functions in plants. It is involved in all major physiological processes such as seed dormancy and germination, root growth, stomatal closure, flowering, iron homoeostasis, hormonal signaling, senescence and contributes to immunity as well as to the adaptive response to abiotic stresses. Therefore, it is not surprising that this gas has become a dominant part of physiological, cellular and molecular biology research. Accordingly, five Plant Nitric Oxide International Meetings have been held since 2006, and the sixth will be organized in 2016 in Granada in Spain. Interestingly, an essential part of the data generated to date indicates that NO is a major component of plant cell signaling and, compared to animals, there is a remarkable degree of similarity in the molecular mechanisms underlying its effects. The field of NO research in plants is still in its infancy and numerous questions remain as yet unanswered or poorly answered, notably those relating to its synthesis and its basis for specificity.

This focus section of Advances in Botanical Research presents a series of 14 chapters highlighting recent insights into NO in plants. We learn from these contributions that NO cooperates with other signaling compounds including hydrogen sulphide and reactive oxygen species, notably the superoxide anion and hydrogen peroxide. As mentioned by J. Hancock and M. Whiteman (Chapter 1), these interactions might be viewed as an interactive and complex web of reactive species determining cellular responses. Other authors illustrate the importance of such interplay in root growth and developmental processes (N. Correa-Aragunde et al., Chapter 3), in programmed cell death (V. Locato et al., Chapter 9), in the establishment of symbiosis (I. Hichri et al. Chapter 10) and in immunity (E. Vandelle et al., Chapter 11; P. Kachroo et al., Chapter 12). In addition to the reactive species, crosstalk also operates between NO and hormones, lipids and the second messengers Ca^{2+} and cyclic GMP. Examples of the occurrence of such crosstalk in auxin signaling and plant immunity are provided by N. Correa-Aragunde et al. (Chapter 3), P. Kachroo et al. (Chapter 12) and Y. Ma and G. Berkowitz (Chapter 14).

Another main issue discussed in these chapters concerns the specificity of NO action. It appears that the specificity of NO signaling is partly governed by its ability to modulate the activity of target proteins through posttranslational modification (PTM) including S-nitrosylation and tyrosine nitration. These NO-dependent PTMs play a fundamental role in the regulation of gene expression (I. Kovacs et al., Chapter 2), auxin signaling (N. Correa-Aragunde et al., Chapter 3), nitrogen assimilation (L. Frungillo et al., Chapter 4), responses to abiotic stresses (F. Corpas et al., Chapter 5) including cadmium exposure (M. Arasimowicz-Jelonek et al., Chapter 6), metabolism (M. C. Romero-Puertas and L. Sandalio, Chapter 7; A. K. Gupta et al., Chapter 8), programmed cell death (V. Locato et al., Chapter 9), symbiosis and immunity (I. Hichri et al. Chapter 10; E. Vandelle et al., Chapter 11; Y. Ma and G. Berkowitz, Chapter 14). Importantly, NO-dependent

PTMs and, more generally, NO functions are dictated by the chemistry of NO in biological contexts and the production of derived species such as nitrosoglutathione resulting from the interaction of NO and reduced glutathione as summarized by F. Corpas et al. (Chapter 5).

Most chapters provide an informative overview of NO functions in a particular physiological process. These contributions underline the importance of combining all the 'omic' sciences together with physiological and genetic approaches. Deciphering the functions and mode of action of NO will also require the application of metabolomic approaches as suggested by M. C. Romero-Puertas and L. Sandalio (Chapter 7), the search of proteins regulated by NO-dependent PTMs in specific cellular compartments (see, for instance, I. Kovacs et al., Chapter 2; A. K. Gupta et al., Chapter 8) as well as a better understanding of the crosstalk between distinct PTMs as discussed by several authors (see, for instance, J. Hancock and M. Whiteman, Chapter 1). Finally, NO being a diffusing gas and a ubiquitous messenger, there is a need to consider how NO is perceived and/or produced by pathogenic and symbiotic microorganisms infecting plants. These poorly investigated but fascinating aspects of NO biology are nicely discussed by I. Hichri et al. (Chapter 10) and M. Sedlářová et al. (Chapter 13).

It has been my pleasure to act as Guest Editor for this focus issue about NO signaling in plants. Also, I am grateful to all the authors for their excellent manuscripts and to Pr. Jean-Pierre Jacquot for inviting me in editing this issue.

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