Preface

During photosynthesis, CO$_2$ has to move from the atmosphere surrounding the leaf to the sub-stomatal internal cavities through the stomata, and from there to the site of carboxylation inside the chloroplast stroma through the mesophyll passing leaf internal gas, liquid, and lipid phases. Stomatal diffusion resistance (or its inverse, conductance) and the enzymatic capacity of the foliage photosynthetic apparatus have been recognized for a long time as important regulatory and limiting factors for photosynthesis, and they are the two main components of commonly used photosynthesis models. While the concept of mesophyll diffusion conductance to CO$_2$ ($g_m$) is not new, the number of reports on $g_m$ (sometimes also designed as leaf internal conductance, $g_i$) has more than doubled during the past decade, due to the increased availability of methods for its assessment. As a consequence, $g_m$ has now been established as an additional key limitation of photosynthesis in plants. The importance of this factor is so great that it can be said that ‘there is a third player in the photosynthesis game’, between stomata and leaf biochemistry. Moreover, $g_m$ is apparently rapidly regulated in response to environmental factors, in a way similar to stomatal conductance. The nature and environmental responses of $g_m$ play a key role in plant photosynthesis under stress, and for differentiation of realized photosynthetic potentials of plants with different foliage architecture. As such, $g_m$ has major implications for plant biology, ecology, and for photosynthesis modelling. These important consequences highlight the need to explore interspecific differences in $g_m$ and its responses to the environment, as well as to study the structural, physiological, and molecular mechanisms underlying the regulation of $g_m$.

The idea for a workshop on ‘Mesophyll conductance to CO$_2$: mechanisms, modelling, and ecological implications’ emerged from the growing number of reports on the topic and from the fact that, until now, no meeting covering this topic had been held despite the increasing number of researchers involved in the topic across the world. Also until now, no comprehensive book or Special Issue covering the entire range of aspects concerning $g_m$ research had been published. We would like to thank the European Science Foundation (and co-sponsors the Spanish Ministry of Science and Innovation, the Govern de les Illes Balears, the Universitat de les Illes Balears, Li-Cor Inc. Biosciences, Geonica Ciencias de la Tierra, the Instituto Mediterráneo de Estudios Avanzados, and Wiley-Blackwell Ltd.) for funding the organization of such a workshop, which was held in Sa Coma (Mallorca) in September 2008; and the Journal of Experimental Botany for commissioning the present Special Issue.

The Special Issue contains a series of papers, most of which arose from the workshop. The issue opens with three review papers already commissioned at the workshop to cover the most important aspects of $g_m$. Pons and co-workers present a review on methodologies to study $g_m$, highlighting the precautions required for its proper assessment. Evans and co-workers review the current state-of-the-art on mechanisms regulating $g_m$, while Niinemets and co-workers discuss the ecophysiological implications of finite and variable $g_m$. In the section on ‘Methodological aspects of $g_m$ and implications for modelling’, Niinemets and co-workers present a report on the influence of $g_m$ on photosynthesis estimations using modelling approaches, while Loreto and co-workers show that using blue light for measurements may cause some artefacts that lead to underestimations of $g_m$. The latter represents the first of a series of ‘Responses of $g_m$ to single environmental factors’. This section opens with a series of controversial papers on the effects of light and CO$_2$ on $g_m$. In these, Tazoe and co-workers present evidence that light and CO$_2$ do not significantly affect $g_m$ estimated using the isotope method in wheat. By contrast, Hassiotou and co-workers found an effect of both factors on $g_m$ this time estimated using the chlorophyll fluorescence method in sclerophyll species of Banksia. Finally, Vrábl and co-workers show an effect of CO$_2$, but not of abscisic acid, on $g_m$ as estimated by both methods—isotopes and chlorophyll fluorescence—in sunflower. In addition, Centritto and co-workers present differences among contrasting rice genotypes in the response of $g_m$ to water stress, Monti and co-workers describe differences on $g_m$ along the plant profile depending on changing light conditions, and Li and co-workers present evidences for higher $g_m$ underlying increased photosynthesis under high nitrogen availability. The next section is on ‘Responses of $g_m$ to interacting environmental factors’. In this section, Flexas and co-workers show that $g_m$ reductions during water stress are fully reversed on cloudy days. Expanding this idea, Gallé and co-workers demonstrate that the effects of water stress on $g_m$ and the delay in its recovery after rewatering are stronger the higher is the prevailing light intensity during the experiment. Similarly, Perez-Martin and co-workers found complex interactions between soil water stress and air vapour pressure deficit on the regulation of $g_m$. The last section deals with ‘Mesophyll conductance in field stressful environments’. In this, Montpied and co-workers show that, in beech trees, $g_m$ displays a large plasticity along the canopy but is only moderately affected seasonally, while Roussel and co-workers found no difference in $g_m$ between high and low water-use-efficient families of Quercus robur. Finally, Niinemets and co-workers found a large diversity in $g_m$ among Australian sclerophyll species, which correlates with leaf structural diversity.
From the reports of this issue, a clearer picture of the physical nature of $g_m$, and of its implication for fundamental biochemical processes, such as photosynthetic carbon fixation, emerges. However, the field is probably still in its infancy, and many controversial issues remain to be resolved. Our efforts to refine current methodologies to estimate $g_m$ have indicated the limits of these methods. The erratic responses to single environmental factors probably reveal a genetic variability that should also be taken into account more rigorously. We hope that this collection of papers will prepare the ground for a wider perception of the importance of leaf mesophyll, and will stimulate new ideas on how to improve our capacity to estimate the diffusive limitations to CO$_2$ acquisition.

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