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Advances in understanding photosynthetic efficiency: responding to the challenges of global climate change

Barry Osmond

Australian National University, Canberra ACT, Australia

Photosynthesis is the single most important biological process on Earth, having made the planetary environment hospitable to bulky heterotrophs, including humankind. The photosynthetic apparatus is complex of about 100 proteins and pigments in chloroplast membranes assembled into two coordinated molecular machines (photosystems 1 and 2) that act as “electrochemical solar cells” that catalyse charge separation to bring about the most oxidising chemistry in biology; to split water and release $\sim 10^{11}$ tons of O_2 into the atmosphere annually. Photosynthesis is also a first responder to global climate change which, ironically, is largely driven by a 10^6 -fold acceleration of CO_2 release from fossil photosynthates in today's energy economies.

Progress in understanding photosynthetic efficiency owes as much to exotic natural systems as it does to targeted loss-of-function mutations of the photosynthetic apparatus. Regulation of light harvesting efficiency in cells and leaves that must cope daily with 10^3 -fold changes in photon fluxes depends on the photobiology of two cycles, the ubiquitous violaxanthin (V)-cycle and the specialised lutein epoxide (Lx)-cycle in leaves of tropical trees that afford photoprotection against photoinactivation in strong light and promote light harvesting in deep shade. Applications of non-intrusive chlorophyll fluorescence analysis and imaging, from cells to remote sensing of photosynthetic efficiency in canopies, will be described. It remains to be seen whether photosynthetic systems can be modelled or managed to mitigate the consequences of our profligate exploitation of fossil photosynthates. Prospects range from naturally occurring gain-of-function mutants of alga *Chlamydomonas reinhardtii* that are very high light resistant to bio-inspired artificial photosynthesis.