

# Functional Plant Biology

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## Contents

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(See photo of participants at CAM 2001)

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| <p>Crassulacean acid metabolism: plasticity in expression, complexity of control<br/> <b>Joseph A. M. Holtum</b>      657–661</p>  | <p>In this short article, a co-convenor of the CAM 2001 conference outlines the significant advances in CAM research that appear in this Special Issue.</p>  |
| <p>Probing the circadian control of phosphoenolpyruvate carboxylase kinase expression in <i>Kalanchoë fedtschenkoi</i><br/> <b>James Hartwell, Gillian A. Nimmo, Malcolm B. Wilkins, Gareth I. Jenkins and Hugh G. Nimmo</b>      663–668</p>                  | <p>These authors investigate whether the circadian control of PEPC kinase expression in CAM plants is an indirect, secondary effect of oscillations in the level of cytosolic malate. Both non-aqueous fractionation and imposition of a temperature change are used to test this hypothesis. The involvement of protein phosphorylation in PEPC kinase expression is also examined.</p>   |
| <p>Environmental, hormonal and circadian regulation of crassulacean acid metabolism expression<br/> <b>Tahar Taybi, John C. Cushman and Anne M. Borland</b>      669–678</p>   | <p>Regulation of genes and enzymes at multiple levels is central to the photosynthetic plasticity of CAM. This review examines some of the primary environmental and hormonal factors controlling this plasticity, as well as inherent circadian regulation. Secondary signals are also considered, with emphasis on the role of cytosolic calcium.</p>  |
| <p>Resistance is useful: diurnal patterns of photosynthesis in C<sub>3</sub> and crassulacean acid metabolism epiphytic bromeliads<br/> <b>Kate Maxwell</b>      679–687</p>   | <p>Features of bromeliads that allow them to compete in their drought-prone habitat may negatively affect CO<sub>2</sub> assimilation and growth rates. Regulation of CO<sub>2</sub> assimilation was studied over the diurnal course in C<sub>3</sub> and CAM bromeliads, with the pattern of Rubisco activation found to differ between the two.</p>   |
| <p>Regulation of Rubisco activity in crassulacean acid metabolism plants: better late than never<br/> <b>Howard Griffiths, Brent Helliker, Andrew Roberts, Richard P. Haslam, Jan Girnus, Wendy E. Robe, Anne M. Borland and Kate Maxwell</b>      689–696</p> | <p>The carboxylation capacity of CAM plants can exceed rates of net CO<sub>2</sub> uptake by an order of magnitude. By measuring diurnal changes in Rubisco activity, these authors explore the role of this enzyme in the maintenance of high carboxylation capacity. Electron transport activity and the effects of drought are also considered.</p>   |
| <p>Metabolic control of photosynthetic electron transport in crassulacean acid metabolism-induced <i>Mesembryanthemum crystallinum</i><br/> <b>Mark Aurel Schöttler, Helmut Kirchhoff, Katharina Siebke and Engelbert Weis</b>      697–705</p>                | <p>Diurnal changes in metabolism mean that CAM plants must cope with dramatic variations in demand for ATP and NADPH. This article examines adaptive responses of the light reactions during the C<sub>3</sub>–CAM transition, and provides evidence for diurnal depression of the quantum efficiency of PSII and transient down-regulation of linear electron transport.</p>  |
| <p>Carbohydrate partitioning in crassulacean acid metabolism plants: reconciling potential conflicts of interest<br/> <b>Anne M. Borland and Antony N. Dodd</b>      707–716</p>   | <p>These authors hypothesize that compartmentation of C<sub>3</sub>- and C<sub>4</sub>-derived carbohydrates contributes to independent regulation of metabolic pathways that constitute CAM, and those that drive growth. Detailed carbon budgets quantify carbon partitioning in C<sub>3</sub> and CAM-induced <i>Mesembryanthemum crystallinum</i>, and stable carbon isotope measurements determine arrangement of carbon pools.</p> |

Cover illustration: Water colour-tinted copperplate of the phosphoenolpyruvate carboxykinase CAM vine *Hoya carnosa* (formerly *Asclepias carnosa*). Drawn and painted by A. T. Gart in 1810.

Sucrose transport across the vacuolar membrane of  
*Ananas comosus*  
**Shelley R. McRae, John T. Christopher,  
J. Andrew C. Smith and Joseph A. M. Holtum** 717–724

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The commercially important CAM bromeliad *A. comosus* (pineapple) stores a large proportion of carbohydrate synthesized during the light period as soluble sugars in the vacuole. Here, data is presented that supports the involvement of a uniporter in vacuolar loading of sucrose.

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Mode of photosynthesis during different life stages of hemiepiphytic *Clusia* species  
**Wolfgang Wanek, Werner Huber, Stefan K. Arndt and Marianne Popp** 725–732

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To assess whether expression of CAM is controlled by ontogenic or environmental factors in *Clusia* spp., carbon isotope discrimination and diurnal acid fluctuations at three life stages were analysed. CAM cycling was evident at all life stages, indicating that CAM expression is triggered primarily by environmental, rather than developmental, factors.

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Nitrogen nutrition during ontogeny of hemiepiphytic *Clusia* species  
**Wolfgang Wanek, Stefan K. Arndt, Werner Huber and Marianne Popp** 733–740

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Primary hemiepiphytes may encounter significantly different levels of available nitrogen in their juvenile canopy habitat and mature terrestrial environment. These authors show that these differences cause distinct changes in the nitrogen acquisition strategies utilized by the various life stages of *Clusia* species.

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Flexibility of nitrogen metabolism in the tropical C<sub>3</sub>–crassulacean acid metabolism tree species, *Clusia minor*  
**Stefan K. Arndt, Wolfgang Wanek, Günter Hoch, Andreas Richter and Marianne Popp** 741–747

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The exceptionally diverse range of habitats occupied by *Clusia* spp. is likely related to the high degree of plasticity of carbon acquisition in these C<sub>3</sub>–CAM intermediates. *Clusia* may exhibit similar plasticity of nitrogen metabolism, and this hypothesis is investigated here via <sup>15</sup>N-labelling experiments and measurements of nitrate reductase activity.

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Short-term plasticity of crassulacean acid metabolism expression in the epiphytic bromeliad, *Tillandsia usneoides*  
**Richard P. Haslam, Anne M. Borland and Howard Griffiths** 749–756

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In plants subjected to frequent water deficit, such as the extreme atmospheric epiphyte *T. usneoides*, flexibility of CAM expression may contribute to the maintenance of water status. These authors use non-invasive *in vivo* manipulation of CO<sub>2</sub> supply to investigate the hypothesis that CAM plasticity also serves to maintain carbon balance.

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Influence of nitrogen supply on the photoprotective response of *Neoregelia cruenta* under high and low light intensity  
**Janaina Fernandes, Ricardo M. Chaloub and Fernanda Reinert** 757–762

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*N. cruenta* is a tank bromeliad that stabilizes the fragile soils of restinga environments while increasing their organic content. By assessing the influence of nitrogen nutrition on pigment content, CAM activity, and photochemical efficiency under high and low light, these authors conclude that elevated leaf nitrogen levels protect *N. cruenta* against photoinhibition.

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Photosynthetic and anatomical characteristics in the C<sub>4</sub>–crassulacean acid metabolism-cycling plant, *Portulaca grandiflora*  
**Lonnie J. Guralnick, Gerald Edwards, Maurice S. B. Ku, Brandon Hockema and Vincent R. Franceschi** 763–773

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This study indicates that the herbaceous annual *P. grandiflora* utilizes both CAM and C<sub>4</sub> photosynthesis, and that these pathways operate independently of one another. CAM activity is upregulated in both leaves and stems during water stress, and the authors suggest that CAM cycling in the leaves may occur exclusively in water-storage tissue.

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Are crassulacean acid metabolism and C<sub>4</sub> photosynthesis incompatible?  
**Rowan F. Sage** 775–785

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There is little evidence to support the operation of C<sub>4</sub> photosynthesis in CAM plants, in spite of biochemical and ecological similarities between the metabolic pathways. This paper reviews evidence for incompatibility between CAM and C<sub>4</sub> metabolism, and examines possible biochemical, anatomical and evolutionary causes for this incompatibility.

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