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Research Letter

RESEARCH LETTER – Environmental Microbiology

OK, thanks! A new mutualism between *Chlamydomonas* and methylobacteria facilitates growth on amino acids and peptides

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One sentence summary: A new mutualism based on carbon-nitrogen exchange between the alga *Chlamydomonas* and *Methylobacterium* spp. improves the growth of both microbes on amino acids and peptides.

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ABSTRACT

Nitrogen is a key nutrient for land plants and phytoplankton in terrestrial and aquatic ecosystems. The model alga *Chlamydomonas reinhardtii* can grow efficiently on several inorganic nitrogen sources (e.g. ammonium, nitrate, nitrite) as well as many amino acids. In this study, we show that *Chlamydomonas* is unable to use proline, hydroxyproline and peptides that contain these amino acids. However, we discovered that algal growth on these substrates is supported in association with *Methylobacterium* spp., and that a mutualistic carbon–nitrogen metabolic exchange between *Chlamydomonas* and *Methylobacterium* spp. is established. Specifically, the mineralization of these amino acids and peptides by *Methylobacterium* spp. produces ammonium that can be assimilated by *Chlamydomonas*, and CO_2 photosynthetically fixed by *Chlamydomonas* yields glycerol that can be assimilated by *Methylobacterium*. As *Chlamydomonas* is an algal ancestor to land plants and *Methylobacterium* is a plant growth-promoting bacterium, this new model of mutualism may facilitate insights into the ecology and evolution of plant–bacterial interactions and design principles of synthetic ecology.

Keywords: Algal–bacterial mutualism; *Chlamydomonas*; *Methylobacterium;* metabolic complementation; nitrogen assimilation

INTRODUCTION

Nitrogen (N) is one of the major limiting nutrients for primary producers like plants and phytoplankton in terrestrial and aquatic ecosystems. Although elemental N is abundant, it is often not bioavailable for most organisms. Plants and phytoplankton depend on the abilities of other microorganisms to transform inaccessible N sources into useable forms like ammonium and nitrate (Hirsch and Mauchline 2015; Pajares and Bohannan 2016). Often, these ecological dependencies evolve and yield stable interactions between organisms with improved efficiency in nutrient exchange. A well-known example is the formation of nodules by N-fixing

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