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Why does *Trichodesmium* fix nitrogen during the day? Special biochemistry linking biogeochemical cycles.

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Cyanobacteria of the genus *Trichodesmium* provide about 80 Tg of fixed nitrogen to the surface ocean per year and contribute to marine biogeochemistry, including the sequestration of carbon dioxide and mobilization of particulate iron. *Trichodesmium* fixes nitrogen in the daylight, despite the incompatibility of the nitrogenase enzyme with oxygen produced during photosynthesis. While the mechanisms protecting nitrogenase remain unclear, all proposed strategies require considerable resource investment. Here we describe a crucial benefit of daytime nitrogen fixation in *Trichodesmium* spp. that may counteract these costs. We analysed diel proteomes of cultured and field populations of *Trichodesmium* in comparison with the marine diazotroph *Crocosphaera watsonii* WH8501, which fixes nitrogen at night. *Trichodesmium's* proteome is extraordinarily dynamic and demonstrates simultaneous photosynthesis and nitrogen fixation, resulting in balanced particulate organic carbon and particulate organic nitrogen production. Unlike *Crocosphaera*, which produces large quantities of glycogen as an energy store for nitrogenase, proteomic evidence is consistent with the idea that *Trichodesmium* reduces the need to produce glycogen by supplying energy directly to nitrogenase via soluble ferredoxin charged by the photosynthesis protein PsaC. This minimizes ballast associated with glycogen, reducing cell density and decreasing sinking velocity, thus supporting *Trichodesmium's* niche as a buoyant, high-light-adapted colony forming cyanobacterium. To occupy its niche of simultaneous nitrogen fixation and photosynthesis, *Trichodesmium* appears to be a conspicuous consumer of iron, and has therefore developed unique iron-acquisition strategies, including the use of iron-rich dust. Particle capture by buoyant *Trichodesmium* colonies may therefore increase the residence time and degradation of mineral iron in the euphotic zone. These findings describe how cellular biochemistry defines and reinforces the ecological and biogeochemical function of these keystone marine diazotrophs, particularly their role as a microbial link in the nitrogen, carbon, and iron cycles.