KN1 - N_2-fixing symbiosis between cyanobacteria and a unicellular alga: evolution and metabolic interactions

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Mutualism is a common symbiotic lifestyle among microorganisms and macro organisms. These systems have remarkable evolutionary adaptations involving cellular and developmental modifications, metabolite exchange, and molecular signaling. In the oceans, the dominant eukaryotic phototrophs are unicellular, and oceanic N_2-fixing symbioses are between cyanobacteria and unicellular algae. Symbiosis between unicellular organisms presents different challenges from multicellular systems since cellular growth must be carefully controlled.

The uncultivated symbiosis between the haptophyte (Prymnesiophyte) *Braarudosphaera bigelowii* and an unusual unicellular cyanobacterium (UCYN-A) involves dramatic genome reduction. UCYN-A lacks photosystem II, Rubisco and the entire TCA cycle, and many other metabolic pathways, but retains photosystem I. However, the entire nitrogen fixation apparatus is intact and using isotopes, it has been shown to fix nitrogen for the haptophyte in return for fixed carbon. However, recently we have found that this unicellular symbiosis may be much more complex than it appears. Whole genome expression patterns suggest that the cyanobacterial diel pattern has shifted to accommodate the daily cycle of photosynthesis in the host. More surprisingly is the pattern of retention of vitamin synthesis genes and dependencies on vitamins. UCYN-A has retained the entire B-12 synthesis pathway even though its B-12 requirements are not clear, suggesting a possible interaction between host and symbiont.Even more surprisingly, we found that the haptophyte host will not take up nitrate, and that UCYN-A continues to fix nitrogen. Thus, the symbiotic interactions may be controlled by multiple interactions, not just the supply of fixed nitrogen. The UCYN-A symbiosis, now known to be comprised of multiple strain families is being reported from a wide array of regions and may be one of the most important N_2 fixers. Understanding this symbiosis is important for understanding global ocean nitrogen fixation, but the unicellular symbioses also provides an interesting model for cellular metabolism and microbial interactions in N_2-fixing symbioses.