# Evolution of photosynthesis

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The evolution of chlorophyll-based phototrophy was one of the most important bioenergetic innovations in the history of life on Earth, but key first-order questions about its evolution remain. Here we present genomic and biochemical data that place new constraints on the acquisition of phototropy in different clades. There are currently six known phlya of bacteria that have chlorophototrophic members; Cyanobacteria, Proteobacteria, Chloroflexi, Chlorobi, Firmicutes, and Acidobacteria. Cyanobacteria perform oxygenic photosynthesis using $H_2O$ as an electron donor, generating $O_2$ as a product. All of the other clades perform anoxygenic photosynthesis using a variety of reduced compounds as electron donors. Despite these differences, all known chlorophototrophs share only three common molecular elements; (bacterio-)chlorophyll, reaction centers, and quinol:electron acceptor oxiodoreductases (complex III).

Chlorins can be classified into two types; chlorophylls and bacteriochlorophylls, with the latter only found in anoxygenic phototrophs. Recent analyses of chlorin biosynthesis pathways provide support for the evolution of chlorophyll preceding that of bactriochloropyll[1].

Reaction centers are proteins that convert light energy into high energy electrons. Two evolutionarily related types of reaction centers exist, RCI and RCII. Anoxygenic phototrophys contain either RCI (Firmicutes, Chlorobi, and Acidobacteria) or RCII (Chloroflexi and Proteobacteria). In oxygenic photosynthesis RCI and RCII are coupled together in series, which allows electrons to be transferred from $H_2O$ to ferredoxin. Evolutionary analysis of reaction centers show that their distribution reflects lateral gene transfer[2].

Complex III proteins convert high energy electrons into a protonmotive force. There are two evolutionarily unrelated complex III's—the $b_6f/bc_1$ superfamily and alternative complex III (ACIII). These enzymes are part of a high potential redox module that is shared with aerobic respiration and denitrification. The distribution and evolutionary relationships of complex III and the high potential module support the inferences from chlorin biosynthesis and reaction centers and demonstrates the remarkable conclusion that most currently known anoxygenic phototrophs acquired photosynthesis after the evolution of aerobic respiration, and therefore after the evolution of oxygenic photosynthesis.

[1] Bryant and Liu (2013) *Adv. Bot. Res.,Volume 66*. [2]. Raymond, *et al* (2002) *Science 298:1616*

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# The zinc isotopic composition of siliceous marine sponges: Investigating nature's sediment traps

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The Zinc (Zn) content and isotopic composition of marine biogenic opal has the potential to yield information about the nutrient availability, utilisation and organic matter export from surface to deep waters. Here, we report the first measurements of Zn isotope composition of deep-sea benthic sponge skeletal elements (spicules) from the Southern Ocean. Our results highlight different Zn uptake and fractionation behaviour between the two major siliceous sponge clades (hexactinellids and demosponges), which is most likely linked to sponge filter-feeding strategy and internal physiology. Hexactinellid spicule Zn isotopic compositions are not fractionated with respect to seawater, and so hold potential as proxies for past ocean Zn cycling. In contrast, demosponge spicules exhibit a wide range of Zn isotopic compositions that are related to the opal Zn concentration, most likely reflecting fractionation processes during feeding. As such, demosponge Zn isotope records may be able to shed light on past changes in photic zone organic matter formation in the ocean.

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