How Corals Make Rocks

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How organisms precipitate carbonates is largely unknown. Stony corals contain more than 30 proteins within their skeleton. Proteomic and genomic analysis of these proteins revealed a set of highly acidic proteins, CARPs (coral acid rich proteins). Simultaneously, we developed a cell culture system for corals in which cells self aggregate into protopolyps that precipitate aragonite on their surfaces. Using the coral cell culture system and cloned, purified CARPs, we followed the formation of individual crystals *in vitro* and on surfaces of protopolyps. The precipitation of aragonite is catalyzed by a Lewis acid type of reaction by the CARPs. Using advanced imaging techniques, including scanning helium ion microscopy, Raman confocal microscopy, and 2 dimensional solid state NMR spectroscopy, we followed the evolution of calcification process. Our results reveal that an amorphous magnesium rich carbonate phase is initially produced at the center of calcification, and subsequently matures into a highly ordered set of aragonite fibers that radiate outwards at approximately 7 micrometers per day. This process is relatively insensitive to changes in pH above 7 strongly suggesting that it is far from thermodynamic equilibrium with the aragonite saturation state. The model for biomineralization for corals appears to have paralogs in many other, distantly related animals as well as eukaryotes, suggesting convergent evolution for the formation of biologically mediated carbonates as well as silicates and phosphates.