Pushing Thermodynamics Uphill: Organisms' Control on Biomineralisation

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Inorganically precipitated calcite, rhombohedral $CaCO_3$, forms easily in nature, as stalagmites and stalactites, as veins in rocks, as sediments in warm seas and in our tea kettle. In veins, it forms large, beautiful crystals but the rhomb is the most thermodynamically stable crystal form. Many organisms produce calcite, such as oysters and coral. Earthworms excrete tiny spherules, wood lice store it on their tummies and perhaps the simplest organism, single celled algae, create exquisite platelets called coccoliths from 20 to 60 individual calcite elements, that are less than a micrometer in the longest dimension. As a biomineral, calcite rarely takes rhombic form. Organisms produce complicated organic molecules that adhere to calcite surfaces, inhibiting growth at some sites, thus enhancing it at others. Depending on its ecological niche, an organism can tailor the calcite to its specific needs.

We try to understand the controls on biomineralisation by studying the remains of organisms and by experimenting in ideal systems, where we can control one variable after the other. The calcite atomic structure orders water in contact and even simple compounds such as ethanol, the shortest organic chain that has both a methyl group and an OH group, binds strongly and orders itself. Adsorbed ions change surface tension and thus, the tendency for organic molecules to adhere. Polysaccharides, extracted from coccolith cultures or other organisms, have the power to control crystallization in the manner determined by the organism. Through a multidisciplinary approach, combining skills from physics, chemistry, mineralogy, biology, engineering, geology and mathematics, from experimental and theoretical directions, from the field scale to the nanometer scale and by studying nature and designing model systems, we are getting closer to understanding the secrets of simple organisms.