Scientists uncover speedometer for crystal growth controlled by biomolecule properties

December 4 2006

From gemstones to transistors, crystals are everywhere in our daily lives. Crystals also make up the mineralized skeletons of all organisms, including seashells and our own teeth and bones. Perhaps the most widely used biominerals are found in the calcium carbonate family. Understanding how this mineral forms is of particular interest because of its widespread occurrence over geologic history and its close relation to the calcium phosphate found in the bones and teeth of all mammals.

One ongoing question is how organisms form these mineralized structures, or biominerals, at a controlled rate, sometimes very rapidly until attaining the prescribed size. For reasons not well understood, this process can also go astray, leading to underdevelopment or unwanted growth such as kidney stones. The speed of mineral formation in both normal and pathological development can sometimes be surprisingly fast. For example, phytoplankton, whose occurrence is so extensive that they are believed to have important controls on earth climate, form fully developed and exquisitely shaped skeletons within a few hours.

In the December 4-8, 2006, online Early Edition of the Proceedings of the National Academy of Sciences, Virginia Tech Postdoctoral Scientist Selim Elhadj and Professor Patricia Dove report that the chemistry of organic molecules control the rate of crystal growth. In collaboration with James De Yoreo at Lawrence Livermore National Laboratory and John Hoyer of the Children’s Hospital of Philadelphia, they learned that nano-quantities of biomolecules frequently found in the tissues of organisms where biominerals develop can cause calcite crystals to grow faster. More importantly, they determined that the speed of growth can be tuned by varying the charge and water-structuring ability of the biomolecules. By finding a relationship between the control of electrical charge and hydrophilicity, respectively, the findings result in a speedometer that predicts the type of molecules that will speed up (or not) crystal growth.

The new insights predict the growth enhancing abilities of amino acids, peptide chains and also explain recent reports of very large growth enhancing effects by natural proteins extracted from the shells of abalone.

Their findings add to intrigue of how proteins and other biomolecules rearrange local water to affect many different aspects of biological systems. To now show that this restructuring also influences the growth of crystals adds new momentum to this research area.

In addition to better understanding how organisms can form biominerals with sophisticated shapes, insights to the roles of biology in crystal formation will improve efforts to interpret ancient environments and climate conditions from some fossils. It could also provide new knowledge for inventing materials that can someday approach the same level of complexity in shape and function as Nature has perfected over millions of years with shells, teeth and bones.

Selim Elhadj received his Ph.D. in Chemical Engineering from Virginia Tech in 2001 and Patricia Dove of Blacksburg, professor of geosciences, is a 1980 and 1984 graduate of Virginia Tech who returned to the university after seven years as a professor of geochemistry at the Georgia Institute of Technology. The paper, “Role of Molecular Charge and Hydrophilicity in Regulating the Kinetics of Crystal Growth,” appears in the online issue ahead of publication in PNAS.

Dove and her research group study the interface between minerals, waters, and biomolecules in biomineralization, cementation, chemical weathering, paleoproxy models, metal and biomolecule binding. Located in the Department of Geosciences, they investigate these processes and the underlying reaction mechanisms through direct, nanoscale observations of mineral-water interactions during growth, dissolution, and nucleation with quantitative measurements of kinetics and surface thermodynamic properties. Most projects involve amorphous and crystalline forms of silica and the carbonate polymorphs.

Source: Virginia Tech

Citation: Scientists uncover speedometer for crystal growth controlled by biomolecule properties (2006, December 4) retrieved 2 July 2024 from https://phys.org/news/2006-12-scientists-uncover-speedometer-crystal-growth.html