

Organic-Mineral Nanoparticle Interactions in the Origin of Life and Calcium Phosphate Nanoparticle Precipitation Kinetics in Bone Biomineralization

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Abstract

The interactions of (pre)biological organic molecules with inorganic minerals has potential implications for a wide diversity of processes from the origin of life to bone biomineralization. We have studied the effect of photocatalytic nanoparticles in promoting a primitive protocell metabolism. In particular, the photocatalytic nanoparticles facilitate a multi-step transmembrane electron transfer reaction with the generation of a transmembrane pH gradient and simultaneous reduction of NAD to NADH. Thus, nanoparticulate minerals may have acted as “prebiotic enzymes” in the origin and early evolution of life. We have also investigated the effects of short oligoglutamic acid peptides ($n = 3-10$), as mimics of acidic sequences in biomineralization proteins, for their role in controlling the kinetics of calcium phosphate nanoparticle precipitation and phase transformation. The peptides had no effect on the initial formation of an amorphous calcium phosphate (ACP) nanoparticulate phase but longer peptides delayed the phase transformation to crystalline hydroxyapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$). It is proposed that occlusion of the peptides within the ACP nanoparticles extends the time needed for calcium ions in ACP to rearrange their structure and to dehydrate in order to transform to crystalline calcium phosphate, hydroxyapatite. The previously proposed role of such peptides in adsorbing on nuclei and thus decreasing nucleation energy is not supported by the present work.

Bionote

Nita Sahai’s research focuses on the physical-chemical aspects of biomolecular and inorganic ion interactions at mineral surfaces in processes relevant to (a) the origins and early evolution of life; (b) crystal nucleation and growth; and (c) bone biomineralization. She earned her Ph.D. at the Johns Hopkins University. Prof. Sahai has been at the Department of Polymer Science, University of Akron since 2011. Prior to that, she obtained tenure and was a Full Professor in the

Department of Geoscience, University of Wisconsin-Madison from 2000-2011. Nita Sahai is a Fellow of the Mineralogical Society of America, the Distinguished Lecturer of the Mineralogical Society of America for 2013-2014, and holds the Ohio Research Scholar in Biomaterials Chair at the University of Akron. She has received awards at various stages of her career, including the NSF Post-Doctoral Fellowship, the NSF CAREER award, the Romnes Faculty Fellowship from the University of Wisconsin-Madison, and the Ohio Research Scholar Chair. Prof. Sahai has served on various committees of the National Academies' on behalf of NASA's mission to search for life across space and time and is currently a member of the National Academies' Committee for Astrobiology and Planetary Science. She was interviewed on the Origins of Life research on *National Public Radio's* programs, *To The Best of Our Knowledge* and *Here and Now*. She has also presented a seminar on Cleveland's *Public Broadcasting Service* channel WVIZ. Prof. Sahai has served on the Editorial board of *Geochimica et Cosmochimica Acta*, *American Mineralogist*, and *Geochemical Transactions* and is currently on the Editorial Board of *Scientific Reports*, *Astrobiology* and *Life*. She has guest-edited two thematic issues of *Elements* magazine (*Origins of Life- Transition from Geochemistry to Biogeochemistry*, 2016; and *Medical and Geochemistry*, 2007). She has also guest-edited a volume, *Medical Mineralogy and Geochemistry* (2006), in the well-known *Reviews in Mineralogy and Geochemistry Series*.