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Liposome-Actuated Enzyme Systems: A Benchmark for Controlling Biomineralization

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Abstract

Key to the realization of versatile nano structures are simple, efficient methods of synthesizing materials that mimic aspects of Biomineralization. Liposome-permeability that controls enzymatic reactions may provide blueprints for bio mineral design.

Keywords: Biomineralization; Enzymes; Liposomes; Enzymatic control; Membrane permeability

Opinion

Although it is difficult to overstate the importance of enzymes in biology, these famous macromolecules are also becoming more prominent in nano biotechnology. The appeal of enzymes to nano scientists is three-fold: first, it is a natural nano scale material; second, its capability to furnish high specificity and efficient chemical conversion (which is its main role in biology); and third, this ability to catalyst a large number of chemical reactions can be exploited in industrial processes, waste treatments, pharmaceutical products, and biosensors. Lipid vesicles (liposomes) are best known as the vehicles for administration of nutrients and pharmaceutical drugs, but they are also a versatile tool for nano technological purposes, because liposomes can be designed such that the lipid membranes become into well-defined nanostructures. By exploiting these exquisite nano species, liposome-based nano compartments that sequester active enzymes can be built simply by synthesizing the liposomes in presence of enzymes [1]. Current biomedical applications include, for example, the entrapment of lysozymes into liposomes in order to develop novel therapies in storage diseases [2]. In another approach, enzyme-containing vesicles have been investigated as possible micro reactor system for the decontamination of industrial wastes [1].

One challenge in fields ranging from nanotechnology to biomaterial science is the design of versatile methodologies to attain the control of enzymatic activity. Although liposomes have been used to encapsulate a wide variety of enzymes the emergent properties of systems in which enzymatic activity is controlled by surrounding liposomes have not been fully explored. Our group recently pioneered the use of designed liposomes as a robust scaffold to produce enzymatic control that does not occurs in a free enzyme system [3]. The lipid membranes of the liposomes entrapping enzymes reported by Municoy et al. are not merely static barriers between the interior and exterior environments; they are dynamic skins [3]. Properties of vesicles at the interface level, such as membrane permeability, tuned through a thermal input, allow a controlled transportation of substrates across the barrier, thereby modulating enzymatic activity externally. We used this nano-assembly to switch the reactivity of ureases through the change of the liposome permeability by means of temperature control. This synergic interplay between enzymes and liposomes that mimicking crucial aspects of cellular biochemistry such as confinement and enzymatic regulation, allows emerging bio systems capable of actively reconstructs its surface from a sacrificial mesoporous silica film to create a fully 3D silica shell on liposomes, through a self-catalyzed precipitation process. In this sense, bio mineralization is an inspiration for materials chemistry. Bio minerals are usually synthesized in aqueous media under ambient conditions, and these approaches can lead to materials with a reduced ecological footprint. Earlier attempts to create bio mineralized materials have mainly focused on homogeneous precipitation from salt solutions that are being alkalinized by the decomposition of urea catalyzed by free ureases [4]. These studies aimed to create nano/micro particle precipitates that can have important applications, such as fuel cells. In contrast, the controlled precipitation described by Municoy et al. is not primarily based in intrinsic enzymatic catalysis. Rather, the

incentive for this work comes from the desire to create shell-controlled enzymatic entities. Such entities are ubiquitous in nature, for example in micro compartment that sequesters ethanolamine metabolism in the bacterium Escherichia coli [5], where conformational flexibility encoded within shells allows selective transportation of components across the barrier. The liposome-controlled enzymatic reconstruction of a 3D interface composed of silica shells on liposomes in the system of Municoy et al. has a similarity to these functional structures within the cell. Municoy et al. showed that subtle changes in temperature have a pronounced impact on the silica precipitation, which in turn determines the morphology of their nanostructures. At high temperature, only some large shapeless particles were observed. In contrast, precipitation at lower temperature affords spherical morphologies which reflect the size and shape of the liposomes because the silica solidifies around them. Temperature was the mechanism for controlling enzymatic activity through membrane permeability and was crucial in the formation of nano structured silica. Some of the most exciting developments in material science concern the design of bio inspired synthesis methods mimicking the remarkable in vivo control of the precipitates morphology, as these features exceed the capabilities of present day in vitro materials engineering. The interplay of control of enzymatic activity and liposome membrane permeability could lead to simple routes to develop intricate bio mineralized structures such as diatoms [6]. It will be interesting to learn more about the role of these parameters in directing bio mineralization. Municoy et al. report a first step in this promising direction. It will also be exciting to explore this bio inspired approach for lantanide-based material synthesis, which would launch the production of a diversity of new functional hybrid nanostructures for advanced applications.

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