Molecular Biomimetics – Peptide-based Materials for Nanotechnology and Medicine

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Introduction: With recent developments of nanoscale engineering in the physical and chemical sciences and advances in molecular biology, molecular biomimetics is combining genetic tools and evolutionary approaches with synthetic nanoscale constructs to create a new hybrid methodology: genetically designed peptide-based molecular materials. Following the fundamental principles of genome-based design, molecular recognition, and self-assembly in nature, we can now use recombinant DNA technologies to design single or multifunctional peptides and peptide-based molecular constructs that can interact with solids and synthetic systems. These genetically engineered peptides for inorganics, GEPI, s have made significant impact as inorganic synthesizers, nanoparticle linkers, and molecular assemblers, or simply as molecular building blocks, in a wide range of fields from chemistry to materials science to medicine.

In materials science and engineering, for the last 25 years, "biomimetics" has meant mimicking biology through creating nano- and micro-structures with complexity and architectures similar to those in biology, such as hard tissues with examples of sea shells, bones, spicules, nanoparticles, and thin films, with the desire that the functions would also be the same [1,2]. Although there has been enormous progress in traditional structural biomimetics, the successes have been limited mostly in developing model micrometer-scale and surface structures, and in a limited diversity of functional materials systems [1-4]. In biology, among the major building blocks, proteins are central to the assembly of biological materials that have highly controlled nanostructures and functions.[4] Under the genetic control of organisms, biological hard tissues are assembled in aqueous environments in mild physiological conditions using biomacromolecules: primarily proteins but also carbohydrates and lipids [5]. Proteins are actively involved in the following functions: transport of raw materials; enzymatic reactions for inorganic synthesis; controlled nucleation, growth, and morphogenesis. In addition, they consistently and uniformly self- and co-assemble subunits into short- and long-range ordered structures.

Approach: As the first step in molecular biomimetics, peptides having shorter sequences compared to proteins are selected through combinatorial mutagenesis as the first-generation peptides based on the fast evolution carried out for a specific material interaction [6]. These genetically engineered peptides for inorganic solids (GEPIs) [6] are now becoming ubiquitous in peptide-based hybrid systems [7-9]. The GEPIs are biocombinatorially are first selected, then their binding and assembly characteristics studied experimentally and computationally, and evolutionary approaches are used for next-generation peptides *via* bioinformatics towards tailored multifunctional molecules. Finally genetic approaches are used in creating fusion molecular constructs, and these are then practically implement in nanotechnology, and biological materials for medical applications (Figure 1).

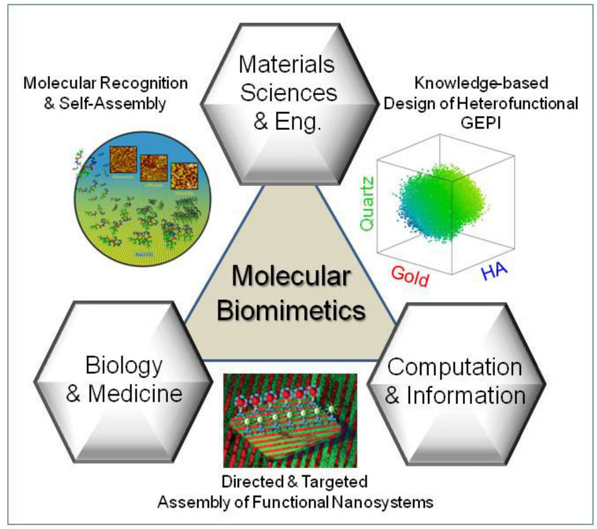

Figure: Molecular Biomimetics is an enabling science and technology field, situated strategically at the confluence of biology and medicine, computation and information sciences, and materials sciences and engineering. The field provides the molecular initiators, linkers, and erectors to enable synthesis, assembly and formation of functional materials and systems for these fields.

Conclusion: As in any self-assembling systems, e.g., metallic atoms on semiconducting substrates during the '70s and '80s leading to vacuum-based technologies towards practical microelectronics and magnetics, and synthetic linker molecules such as thiols and silanes during the '80s and '90s leading to self-assembled monolayer based systems, the GEPIs [7-8] also offer major challenges in the understanding of fundamental aspects of binding to and assembly on solids, with enormous opportunities in using GEPIs in the development of a new generation of peptide-based molecular materials and systems, based in water, both in practical nanotechnology and molecular medicine during this decade and beyond.

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