IWBSBA Grand Challenges

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Recent advancements in the nanotechnology domain have brought forth a plethora of novel nanomaterials (*e.g.*, nanotubes, nanowires, nanoparticles, quantum dots, among others) and materials' fabrication methodologies. When combined with state-of-the-art nano- and micro- imaging and analyses techniques (*e.g.*, scanning tunneling microscopy (STM), tunneling electron microscopy (TEM), Raman spectroscopy, among others), a new generation of hybrid materials and high-performance multifunctional systems have emerged. For instance, by intentionally manipulating molecular structures and orientations, a variety of sensing and actuation transduction mechanisms can be encoded within multi-component nanocomposite architectures to create high-performance piezoresistive, piezoelectric, thermoelectric, or self-healing systems.

In addition to creating higher performance multifunctional systems, the versatility of nano- and micro-fabrication have permitted the design and fabrication of bio-inspired and biomimetic structures that far exceed the performance of current-generation devices. Nature has successfully demonstrated that its creations balance between various unique materials, assemblies, and architectures to achieve optimal performance and functionality. For example, human skins are inherently multifunctional (*i.e.*, capable of multi-modal sensing, actuation, healing, among others), birds can fly and change its wing structure under different conditions, and amphibians possess unique respiratory structures that allow them to adapt to both aquatic and land environments. As a result, advanced material systems such as the morphing wing for improving aerodynamic performance, artificial hair cells for monitoring fluid flow, and self-healing cementitious composites are some of the attempts that have been proposed to imitate the various functions observed in nature's creations. Despite the recent progress in developing bio-inspired material systems, the performance of these artificial structures cannot match their biological counterparts. Particularly, the current generation of bio-inspired structures only seeks to mimic biological function through the use of materials and technologies that are drastically different than those offered by nature.

Thus, so as to match and even exceed the performance of biological structures, further developments in the bio-nanotechnology field of study is direly needed. Not only should bio-inspiration be drawn to mimic the final performance of the material, but also, the design, fabrication, and assembly of next generation sensors and actuators should also follow biological and cellular assembly of nanostructures and functional molecules. By unlocking the mysteries of how nature assembles its complex and unique structures (*e.g.*, filiform hairs, muscles, wings, among others) beginning at cellular length scales, one can mimic bio-manufacturing and further enhance or tailor its performance for the desired application. Understanding the interactions between all components of complex biological structures can also enhance the feasibility to imitate and create novel and sophisticated bio-sensors/actuators. It is expected that future self-assembly fabrication techniques will be autonomously driven by DNA-like coded instruction sets already built into the molecular structure of materials and the fabrication environment.