Panel Discussion on the Role of Mechanics in the Development of Biologically Inspired Materials

June 5, 2000

Orlando, FL

The panel consisted of Minoo Dastoor (NASA), Randy Shrogren (USDA), Mehmet Sarikaya (Univ. of Washington), Paul Calvert (Univ. of Arizona), and Ken Perry (Echobio). The panel was moderated by Hugh Bruck (Univ. of Maryland).

The discussion began with Minoo discussing the objectives of the programs he is funding. NASA's current space missions involve humans in low earth orbit. In the future, missions will have longer range and duration, requiring a new focus on the development of self-autonomous systems for the health and safety of astronauts, increasing affordability, and increasing human productivity. Missions will require 4 to 6 humans performing jobs that are the equivalent of 60, precipitating the need for more human-machine symbiosis. Systems will evolve from diagnostic to prognostic, which will be accomplished by integrating biology, nanotechnology, and information technology.

Randy then discussed agricultural applications for the USDA, whose mission is to increase farmer productivity and markets for farming products. There is a current excess of food and by-products that necessitate the need to develop new food and industrial uses for these materials. Some of these uses can be accomplished by substituting natural materials for synthetics, but require an understanding of the structure and mechanics of food products. Randy then discussed some of his recent research involving the substitution of starch for polystyrene foams.

Paul mentioned that some of the shape change problems in wood and agriculture products might be neutralized through making allowances in the design process. Such problems exist with any low temperature materials. There is a need to understand modeling wet soft materials, liquid flows, inhomogeneous structures in order to predict changes in pH, ionic bonding, etc. as a consequence of applied stresses. Fracture models in biologically inspired materials need to be more complex. Design optimization is also an issue, but require microscale measurements of mechanical properties.

Mehmet emphasized the need for structure/property relationships at all scales in order to achieve biomimcry with synthetic materials. A fundamental understanding of the biological/physiological foundations through genetics processing and magnetobacterium may be one way of developing multi-scale models.

Ken is a consultant to the electronics, consumer products industry that focuses on the commercial use of biomimcry to develop multifunctional materials with sensitivity to the environment. Such concepts are epitomized by developing biodegradable synthetic materials, i.e. materials that are engineered to fail after their use is complete. Companies also want to use biomimcry to find ways to reduce cost, energy, material, and waste in making products.

KT Ramesh from Johns Hopkins discussed the coupling of fluid flow and ionic transport mechanisms. Idealizations are needed in developing models, but they can not be linearized. Data is need, along with computational capabilities, but some solutions can be found through intuition. Paul mentioned the failure in finding synthetic replacements for cartiledge, to which KT responded that polymeric scaffolds have been developed for promoting tissue growth.

Nancy Sottas from the Univ. of Illinois wanted a qualification of multi-functionality. Minoo responded by saying that multi-functionality means structures can do more than one thing. For example, water can serve as a radiation shield, but design principles are needed to exploit these materials. He then proceeded to discuss the difficulties of biologic optimization that requires discriminating between local and global optimization. Ken mentioned that combining sensor and transport mechanisms in multifunctional materials can save space, but that the dimensional instability in biologic optimization may be solved by designing in redundant systems. Minoo followed up by remarking that emergent properties can be developed through complexity as Murray Gellman was investigating the Santa Fe Institute. As an example, he mentioned that the properties of galaxies were different than solar systems which are different from planets.

A question was then asked about biosensors with silicon substrates. Mehmet responded that these systems couple organisms with computers, making "slugs" that can respond to external stimuli or biomimetic computers. Paul mentioned that these systems can lead to flexible electronics to replace brittle silicon. Sandra Whaley of UT-Austin suggested nanoparticles, which Paul thought required a better understanding of how close two particles have to be to communicate. Mehmet mentioned a recent article in the June 2000 edition of "Scientific America" that discussed molecular computing. He also thought we need to focus more on the dynamic behavior of systems to account for transient responses.

Ken thought we need to focus on new methodologies for developing models to design biologically inspired materials. Paul asked how we design cell phones to handle impact loading. Ken responded that the design process in industry is largely trial and error and uses a linear approach.

The discussion was concluded with a general consensus that more multi-scale modeling is needed for the development of biologically inspired materials. Mechanics will play an important role in the development of these models. Also, more unorthodox design approaches using complexity and redundant systems need to be employed. The moderator pointed out that modifying the educational curriculum to reflect these needs will be just as important in training the next generation of engineers and scientists to develop biologically inspired materials.