Mar 19, 2020

Architecture in biological materials: a template for toughness enhancement, or a siren song?

Haneesh Kesari

Assistant Professor of Engineering, Brown University, Providence, RI

ABSTRACT:

Structural biological materials, such as animal bones and shells, display remarkable mechanical properties despite being composed of quite simple and ordinary constituent materials. For example, the toughness of nacre, a structural biological material found in the shells of some mollusks, is orders of magnitude higher than that of its primary constituent—the calcium based mineral aragonite. A number of structural biological materials that display toughness enhancement also possess a lamellar architecture consisting of alternating layers of ceramic and organic phases. It is believed that a structural biological material's intricate architecture—the geometric arrangement of these phases—is responsible for the observed property enhancements. Within the bio-mimetics community, there is currently great interest in reproducing these architectures in synthetic materials using micro-fabrication and 3D printing in order to achieve the property enhancements observed in structural biological materials.

In this talk I will present experimental and computational mechanics results that show that correctly identifying the connection between a structural biological material's architecture and any property enhancements can be a very delicate process. Specifically, I will present experiments that characterize the toughness properties of the skeletal elements of the marine sponge Euplectella aspergillum, called spicules. I will show that despite possessing a lamellar architecture that is very similar to that seen in nacre, the spicules do not display a significant toughness enhancement. Through mechanics modeling, I argue that the spicule's lamellar architecture is connected to their ability to bend more without failing, i.e., to their strength, rather than their toughness. These results serve as a reminder that any efforts aimed at reproducing a structural biological material's architecture and property enhancements in synthetic materials should be prefaced by a careful investigation of the structural biological material itself.

BIOGRAPHY:

Dr. Kesari is currently an Assistant Professor of Engineering at Brown University. He started at Brown in 2013, where he is affiliated with the Solid Mechanics group. Previously, he obtained his Ph.D. (with Adrian Lew and Wei Cai) and M.S. degrees from Stanford University in 2011 and 2007, respectively, and his B.S. degree from Indian Institute of Technology, all in Mechanical Engineering. At Stanford, he was awarded the Juan Simo Outstanding Thesis award and the Herbert Kunzel Fellowship. He was recently awarded the Haythornthwaite fellowship by the American Society of Mechanical Engineers and the Salomon award by Brown University. He is interested in applied solid mechanics problems, and uses a synergistic combination of tools from both computational and experimental solid mechanics. His research has received a commendation as part of the James Clerk Maxwell Young writer's prize, has appeared in journals such as PNAS, Scientific Reports, and the Proceedings of the Royal Society, and has been featured by NASA, NSF, Scientific American, and the American Ceramics Society among others.