Natural Armor: An Encyclopedia of Protective Engineering Designs

Christine Ortiz
Associate Professor of Materials Science and Engineering
Massachusetts Institute of Technology

Biological exoskeletons or "natural armor" systems are multilayered, hierarchical structures that serve many functions, in particular protective mechanical roles such as; penetration, wear, and scratch resistance, minimization of back deflection and potential blunt trauma, damage detection and sensing, self-repair and regeneration, and, in certain cases, flexibility and mobility. We can learn much from biological organisms that have evolved over millions of years a veritable encyclopedia of environmentally-friendly engineering designs for protection against specific predatory and environmental threats. Natural armor functions efficiently by elegantly balancing protection, tissue damage tolerance, weight, and mobility requirements to maximize survivability. In order to elucidate the design principles of these fascinating materials, nanomechanics methodologies have been employed including; the measurement and prediction of extremely small forces and displacements, the quantification of nanoscale spatially-varying mechanical properties, the identification of local constitutive laws, the formulation of molecular-level structure-property relationships, and the investigation of new mechanical phenomena existing at small length scales. This talk will focus on a number of classes of natural armor: flexible, transparent, those that exhibit resistance to biochemical toxins, kinetic attacks, extreme thermal fluctuations, and blast. Model systems to be discussed include "living fossils" such as armored fish, deep sea hydrothermal vent and antarctic molluscs, echinoderms and molluscs with articulating plates (e.g. chitons, urchins), and the transparent exoskeletons of certain crustaceans and pteropods, etc.