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Proof**CONTROL ID:** 667746**CONTACT (NAME ONLY):** Juha Song**Abstract Details****PRESENTATION TYPE:** Oral Presentation Preferred**SYMPOSIUM:** FF: Mechanical Behavior of Nanomaterials—Experiments and Modeling**KEYWORDS:** Properties / Mechanical / strength, Composition & Microstructure / Material Type / biomaterial.**Abstract****TITLE:** Threat-protection response of natural exoskeletons**AUTHORS (FIRST NAME, LAST NAME):** Juha Song¹, Mary C. Boyce², Christine Ortiz¹**INSTITUTIONS (ALL):** 1. Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA.

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ABSTRACT BODY: It is hypothesized that the functional design of biological exoskeletons are intimately linked to their corresponding environmental and predatory threats (e.g. biting teeth, bird beaks, the crushing, peeling, and cutting claws of crabs, etc.) through the evolutionary process. During a predatory attack, the natural armor, as well as the attack structure, will undergo complex multiaxial deformations since generally both have mechanical properties that are comparable. The nature, interaction, and coupling between the armor and threat stress and strain fields are critical to the understanding the functional design specificity of the armor in achieving sufficient protection and maximizing survivability of the animal. In this study, we investigate this topic using a model system, the fish *Polypterus senegalus*, which has an exoskeleton composed of highly mineralized scales. The primary predators of *P. senegalus* are known to be its own species or its carnivorous vertebrate relatives and biting take place during both territorial fighting and feeding. Finite element analysis models of the geometry, multilayered structure, and mechanical properties of both the scale and tooth were constructed and a virtual penetrating biting event simulated on loading and unloading. For the tooth model, optical microscopy images of *P. senegalus* teeth showed conical geometry with an averaged end-radius of ~15 μm (ranging from ~ 3 μm to ~ 44 μm) and two material layers; a cone of dentin capped by an outer layer of enameloid. The scale of *P. senegalus* was modeled as quad-layered in accord with its known structure (ganoine, dentin, isopedine, and bone). The elastic and plastic mechanical properties of both the tooth and scale individual material layers utilized in the simulations were quantified experimentally via instrumented indentation. Since the mechanical properties of the threat and armor were comparable, deformation occurred simultaneously in both structures. A higher stress concentration and greater degree of deformation occurred in the tooth compared to the armor, due to the higher curvature compared to the armor. Plasticity took place primarily in the softer underlying dentin layer of the tooth. Deformable and relatively sharp indenters, e.g. the fish tooth, significantly reduce the critical stress fields and plastic deformation inside the armor compared to theoretically rigid indenters. Parametric studies show that smaller end-radius and a thinner enamel layer of the tooth led to larger plastic deformation of the tooth dentin and smaller penetration depth into the scale. These results are consistent with the concept of evolutionary-driven "length-scale matching" between the protective structure its corresponding threat, which can be traced back to "Darwin's finches" whereby the size scale of their beaks (for approximately the same size birds) were adapted to the size scale of the food sources (e.g. seeds).

(No Table Selected)