Beyond Fossils: Bridging Fields for Deeper Palaeobiological Insights

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Despite millions of years of fossilisation, the microscopic structure of fossil bones remains intact. Remarkably, within the fossilised tissues, key aspects of the life history of the animal are archived. Here, I will present highlights of my research on fossil bone microstructure to show how this has led to a better understanding of the biology of extinct animals such as, nonavian dinosaurs, Mesozoic birds and nonmammalian therapsids. Using case studies, I will demonstrate how collaborations across scientific disciplines, and the use of cross cutting methodologies such as finite element analyses, porosity modelling, biomechanical testing etc., have permitted deeper insight into the adaptation and functioning of skeletal structures of both extant and extinct animals. Additionally, I will briefly outline my approaches to communicating my research to the wider public and I will highlight my current research exploring how palaeosciences is communicated globally.

Bits, bobs and biomechanics: Reconstructing the feeding, anatomy and materials of massive sharks from limited samples

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The filter elements (gill rakers) of basking shark species have remained unmistakable structures in the fossil record for >40 million years. This suggests that extinct basking sharks—like the modern species—also fed by gaping their mouths to filter plankton. Yet, we know surprisingly little about the ecologies of these ocean giants and how their filters work, due to the difficulty studying wild sharks and the rarity of well-preserved specimens. We addressed this challenge collaboratively—uniting biomaterials, robotics, biologging and architectural design—integrating from animal behavior down to the filter's structural building blocks. First, we constructed a bio-realistic skeletal model of feeding sharks, integrating anatomy from museum and beached specimens; bio-logging videos and photogrammetry; and diverse multi-scale imaging. The resultant poseable "digital puppet" captures the coordinated motion of joints as controllable parameters, reproducing—digitally and in 3D—how animals deploy their filters into flow. High-resolution imaging and materials characterization showed gill rakers' geometries create architectures with distinct behaviors in flow, imparting an emergent stiffness gradient to the filter, with thousands of arrayed rakers. We discovered rakers are not keratin (as thought) but exceptionally modified denticles, adapted for flexibility and stiffness, with the highest aspect ratio of any dental structure in nature (e.g. teeth, tusks). Particle image velocimetry of rakers and artificial mimics (with varied morphologies, tested at multiple flow speeds) clarified filtration mechanics: accumulation of simulated plankton under certain conditions suggests basking sharks swim at optimal speeds for feeding and that a small architectural feature—only appreciated when rakers are arrayed together—is critical to efficiently transport food and reduce filter clogging. The hierarchical design and performance of basking shark filters show how even microarchitecture can profoundly affect biomechanics, with adaptation of both material and geometry in evolution enabling novel dietary niches. The findings show the value of interdisciplinary approaches for studying large and elusive wildlife, offer inspiration for advanced filtration tools, and support reconstruction of ecologies from limited fossil evidence.