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Using computational fluid dynamics to test functional and ecological hypotheses in fossil taxa

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Reconstructing how ancient organisms moved and fed is a major focus of study in palaeontology. Traditionally, this has been hampered by a lack of objective data on the functional morphology of extinct species, especially those without a clear modern analogue. However, cutting-edge techniques for characterizing specimens digitally and in three dimensions, coupled with state-of-the-art computer models, now provide a robust framework for testing functional and ecological hypotheses even in problematic fossil taxa. One such approach is computational fluid dynamics (CFD), a method for simulating fluid flows around objects that has primarily been applied to complex engineering-design problems. Here, I will present three case studies of CFD applied to fossil taxa, spanning a range of specimen sizes, taxonomic groups and geological ages. First, I will show how CFD enabled a rigorous test of hypothesized feeding modes in an enigmatic Ediacaran organism with three-fold symmetry, revealing previously unappreciated complexity of pre-Cambrian ecosystems. Second, I will show how CFD was used to evaluate hydrodynamic performance and feeding in Cambrian stem-group echinoderms, shedding light on the probable feeding strategy of the latest common ancestor of all deuterostomes. Third, I will show how CFD allowed us to explore the link between form and function in Mesozoic ichthyosaurs. These case studies serve to demonstrate the enormous potential of CFD for addressing long-standing hypotheses for a variety of fossil taxa, opening up an exciting new avenue in palaeontological studies of functional morphology.