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Fish out of water: hydrodynamics from swimming to jumping[1]

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Aquatic jumping is widely revered with awe by humans, as evidenced in the popularity of the Discovery Channels "Shark Week" episodes on jumping sharks. Jumping by any organism requires high bursts of power and muscular coordination. Aquatic jumpers in particular must produce thrust in manners compatible with the transition from one fluid media to the next, specifically accounting for the drastic drop in fluid density (and thus force-producing ability) between water and air. Jumping for food requires more precision than jumping for migration or escape. Organisms ranging in size from large marine mammals and sharks (length O(10m)) to small copepods (length O(0.01m)) have developed aquatic jumping strategies compatible with their size and survival goals (e.g., prey capture, escape, mating or migration). Larger animals tend to employ burst swimming for short periods before water exit, and smaller swimming fish tend to use S- or C-start acceleration maneuvers to generate jump thrust. Even smaller organisms such as copepods exhibit jumping behaviors using unique hydrodynamic mechanisms for impulsive vortical formation. However, water escape by engineered machines has yet to be mastered. Water-to-air transitions in vehicles are typically accomplished through high-momentum, high fuel consumption, artificial jets or propellers. The synergistic multi-propulsor relationships identified from fish swimming investigations could be paradigm-shifting for the design of bioinspired multiphase vehicles. This talk will discuss how studies of freely swimming fish and flapping foils can inform jumping analysis and our understanding of fin-fin interactions in complex fish maneuvers.

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