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Biomimetics and Tubercles on Flippers for Hydrodynamic Flow Control

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The biomimetic approach seeks to incorporate designs based on biological organisms into engineered technologies. Biomimetics can be used to engineer machines that emulate the performance of organisms, particularly in instances where the organism's performance exceeds current mechanical technology or provides new directions to solve existing problems. The ability to control the flow of water around the body dictates the performance of marine mammals in the aquatic environment. Morphological specializations of marine mammals afford mechanisms for passive flow control. Aside from the design of the body, which minimizes drag, the morphology of the appendages provide hydrodynamic advantages with respect to drag, lift, thrust, and stall. Of particular interest are the pectoral flippers of the humpback whale (*Megaptera novaeangliae*). These flippers act as wing-like structures to provide hydrodynamic lift for maneuvering. The use of any such wing-like structure in making small radius turns to enhance both agility and maneuverability is constrained by performance associated with stall. Delay of stall can be accomplished passively by modification of the flipper leading edge. The design of the flippers includes prominent leading edge bumps or tubercles. Such a design is exhibited by the leading edge tubercles on the flippers of humpback whales. These novel morphological structures induce a spanwise flow field of separated vortices alternating with regions of accelerated flow. The coupled flow regions maintain areas of attached flow and delay stall to high angles of attack. The morphological features of humpback whales for flow control can be utilized in the biomimetic design of engineered structures and commercial products for increased hydrodynamic performance. Nature retains a store of untouched knowledge, which would be beneficial in advancing technology.