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Short revolving wings enable hovering animals to avoid stall and reduce drag DAVID LENTINK, JAN W. KRUYT, Department of Mechanical Engineering, Stanford University, GERTJAN F. HEIJST, Department of Applied Physics, Eindhoven University of Technology, DOUGLAS L. ALTSHULER, Department of Zoology, University of British Columbia — Long and slender wings reduce the drag of airplanes, helicopters, and gliding animals, which operate at low angle of attack (incidence). Remarkably, there is no evidence for such influence of wing aspect ratio on the energetics of hovering animals that operate their wings at much higher incidence. High incidence causes aircraft wings to stall, hovering animals avoid stall by generating an attached vortex along the leading edge of their wings that elevates lift. Hypotheses that explain this capability include the necessity for a short radial distance between the shoulder joint and wing tip, measured in chord lengths, instead of the long tip-to-tip distance that elevates aircraft performance. This stems from how hovering animals revolve their wings around a joint, a condition for which the precise effect of aspect ratio on stall performance is unknown. Here we show that the attachment of the leading edge vortex is determined by wing aspect ratio with respect to the center of rotation–for a suite of aspect ratios that represent both animal and aircraft wings. The vortex remains attached when the local radius is shorter than 4 chord lengths, and separates outboard on more slender wings. Like most other hovering animals, hummingbirds have wing aspect ratios between 3 and 4, much stubbier than helicopters. Our results show this makes their wings robust against flow separation, which reduces drag below values obtained with more slender wings. This revises our understanding of how aspect ratio improves performance at low Reynolds numbers.

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