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Wing and fin motions share universal principles

Tricks common to animals from insects to whales could inspire designs for air and water vehicles.

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Whale tails and bird wings bend in similar ways as they move through water and air.

Most animals that fly or swim bend their wings or fins in similar geometrical proportions and by similar angles, a study says. The seemingly universal principle, which applies to creatures as diverse as moths and sharks, holds lessons for researchers designing devices that propel themselves through air or water. The work is published today in *Nature Communications*[1].

The quest to develop flying machines based on the aerodynamics of flapping wings is hampered by a lack of information about how birds achieve stability and control. So even though the earliest dreams of human flight, from the story of Icarus to the designs of Leonardo da Vinci, attempted to emulate birds, practical designs from the Wright brothers onwards have focused on the stationary aerofoil wing. Working flapping-wing devices have been built only very recently[2, 3].

Scientific opinion has varied on whether the fact that animal wings are flexible, rather than rigid like the wings of an aeroplane, helps or hinders the production of thrust. John Costello, a biologist at Providence College in Rhode Island, and his colleagues thought that the flexibility might be key to natural fight, so they decided to look at just how real animal wings deform.

Feathers and fins

They suspected that similar bending effects would be evident in wings and in fins and flukes used for propulsion in water. In fact, they were initially motivated by their work on a project for the US Office of Naval Research to develop a biologically inspired “jellyfish vehicle”[4, 5]. That work, says Costello, showed that “the addition of a simple passive flap to an otherwise fairly rigid bending surface resulted in orders of magnitude increases in propulsive performance”.

The researchers combed video websites including YouTube and Vimeo for footage of species ranging from fruit flies to bats and from molluscs to humpback whales. For all the vast diversity of propulsor shapes and structures — gossamer-thin membranes, feathered wings, thick and heavy whale tails — the researchers found little variation in certain variables, which they measured essentially by hand. Specifically, across 59 species the distance from the point where bending starts to the wing base tended to be around two-thirds of the total wing length; and the maximum angle of bending was confined within the range of about 15° to 38°.

Animals with very different evolutionary backgrounds therefore have all found the same solution to a common problem. “Their evolution has been governed by the physical laws that determine fluid interactions,” says Costello. “It doesn’t matter whether they originated from crawling, walking or jumping ancestors; once they adapted to a fluid, they evolved within a system determined by a common set of limits.”

What is most surprising about the findings is that all these animals have converged on what seems to be a universal law, despite having bodies with different anatomies and physiology that are made of different materials, says Graham Taylor, who studies animal flight at the University of Oxford, UK. “The comparatively flimsy wing of an insect deforms to the same extent in flight as does the powerful, fleshy tail fluke of a killer whale,” he adds.

Before the findings can be used in aeronautical engineering, more needs to be known about the benefits of the narrow range of bending motions, says Costello. “Maybe then the advantages that these animals have found in these traits can be translated into human designs.”

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References

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