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AVIANS TO AIRPLANES: BIOMIMICRY IN FLIGHT AND WING DESIGN

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In 1903, Orville and Wilbur Wright invented the first heavier-than-air machine capable of powered, sustained, and controlled flight. Though rudimentary, the brothers' apparatus laid the groundwork for far more complex aircrafts. Further technological breakthroughs in the 20th century advanced their fabric-covered, wood-carved planes to sophisticated vehicles capable of traveling at high altitudes and great speeds for long periods of time.[1] The invention of human flight has reshaped our world––now, international travel can be accomplished in a single day, rather than several months.

Of course, humans did not invent flight. Thirteen thousand species of warm-blooded vertebrates, as well as almost a million species of insects, have possessed the ability to fly for millions of years.[2] These flying groups have evolved sophisticated structures made up of wings to generate and maintain lift; muscles to flap, twist, and plunge; and sensing systems for guidance and maneuverability. Wings can adapt to sudden changes in the environment, such as wind gusts, giving them incredible flight stability and control.[4] Acknowledging this, researchers have studied the morphological characteristics and functions of biological flight in an attempt to improve airplane design. And now, designers are beginning to model wing and aircraft designs off of pre-existing ones––the ones found on birds, bats, and insects. Applications of animal flight to its mechanical counterparts would make aircrafts faster, as well as more efficient and ecofriendly.[5]

But how does flight work, anyway? Before delving into recent studies of flier morphology and subsequent advances in airplane design, we must first understand the fundamentals of animal and aircraft flight. An object in flight is constantly engaged in a tug of war between lift, the upward force, and weight, the downward force provided by gravity. Two other lateral forces, thrust and drag, also compete. Birds and animals' muscles provide thrust, while engines generate thrust for aircrafts. The opposing force, drag, is a result of air resistance, but is counteracted by thrust and can be reduced by increasing the aerodynamics of the flying body. The wing, or airfoil, provides the lift required to fly.[6] To take off and maintain flight, lift must overcome weight, and thrust must overcome drag.

The most puzzling of these forces is perhaps lift. Lift can be understood through the lens of Bernoulli's Principle, which states that as any fluid, including air, moves faster, it produces less pressure.[7]

As an airplane or bird moves, air is split above and below its wing. To ensure that the air reaches the same endpoint along the

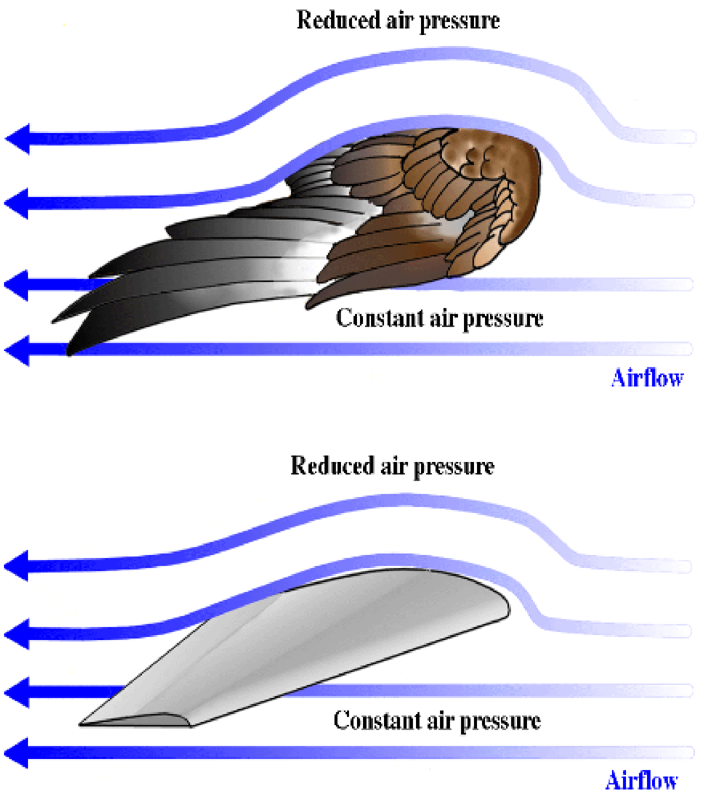

Figure 1: Animal and aircraft wings utilize similar mechanisms to fly. *Both have a curvature that creates reduced air pressure across the top of the wing, which allows the animal or aircraft to achieve maximum lift. In the public domain.*

back edge of the wing, the air that moves over the curved, longer surface of the wing speeds up. The faster air moving over the airfoil produces less pressure than the air moving under. And since there is more pressure pushing the wing up than there is pushing the wing down, the air below the wing produces lift. Whether an aircraft or flying animal flies fast, is more agile/maneuverable, or is more energy efficient depends on both thrust, as well as the flier's ability to generate lift.[5] This is affected by a wide range of factors––the camber (or curve), size, and thickness of each wing, as well as its positioning on the fuselage and its angle relative to the plane body.

As is the case with flying animals, different wing configurations perform best for different types of flight. Perhaps the most important aspect of these configurations are flaps and ailerons. Flaps increase lift or drag depending on their configuration, while ailerons change roll, the rotation around the axis running from nose to tail. The horizontal and vertical stabilizers on the tail of the aircraft have components called elevators and rudders, which control pitch, nose up or down, and yaw, left or right, respectively.[1]

20th century engineers achieved this extensive knowledge on aircraft design and flight performance through theoretical studies, use of wind tunnels, computer modeling, and actual flight tests.[1] But now, shifting their focus to model wing and aircraft designs of flying animals. Natural selection has fine-tuned these animals' flight systems, allowing them to truly optimize the "tug of war" between the four forces behind flight. Unlike the defined components on a man-made wing, birds' wings are one fluid entity, connected seamlessly to their muscles. To pitch up or down, birds simply angle their wings up or down; to control yaw, they twist their wing tips left or right. This is accomplished through wing morphing, the ability to modify wing shape to accommodate different aerodynamic requirements. An aircraft with morphing wings would have greater agility and aerodynamic efficiency than one that requires separate, hinged panels to control motion.[8]

Such an aircraft wing has been designed by NASA and MIT researchers, as shown in Figure 3. The team's design, which uses tiny lightweight pieces called "digital materials," ensures that the whole wing shape can be altered with the activation of two motors, which apply a pressure to each wingtip that twists the wing uniformly along its length.[9] Neil Gershenfeld, director of MIT's Center for Bits and Atoms (CBA), explains that previous attempts at morphing wings failed because they used mechanical control structures to deform the wing. These structures were so heavy that any efficiency advantages provided by the smoother wing surface were lost. But according to Gershenfeld, this new design makes "the whole wing the mechanism. It's not something we put into the wing." Millions of years of bird

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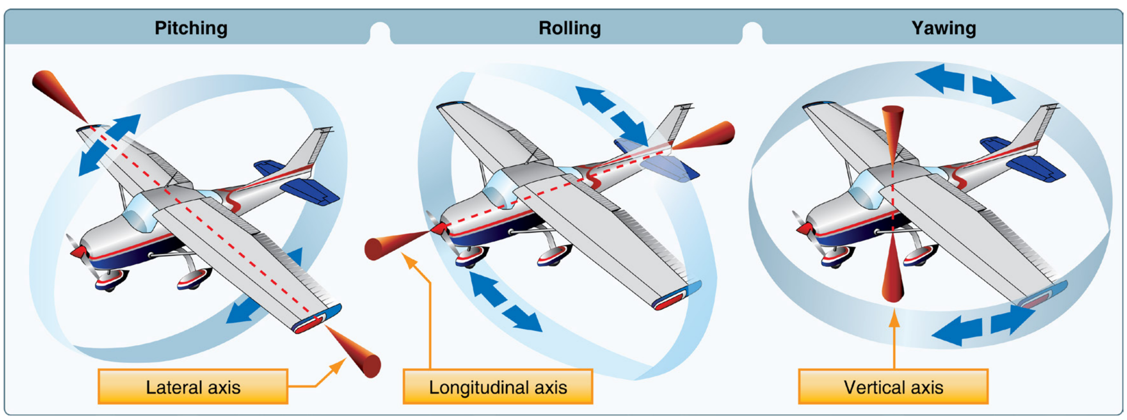

Figure 2: Aircrafts can move in multiple ways across the lateral, longitudinal, and vertical axes. *Pitch is the nose up or down movement, while rolling is the rotation around the nose-to-tail axis. Yawing is a left-to-right motion. Image licensed under CC BY-NC 4.0.*

Figure 3: Researchers' morphing wing can twist and change shape seamlessly when pressure is applied to each wingtip. *In the public domain.*

evolution prove the same thing––the most efficient fliers use their wings as undivided bodies, not structures consisting of individually controlled flaps or ailerons.

Other scientists have recognized that a bird wing is composed not only of an integrated musculo-skeletal system, but is also covered in overlapping feathers. These feathers employ a folding mechanism that serve as a sort of extension of the morphing wing, amplifying the effects of the changing wing shape.[8]

These biomimetic designs have developed past research and into industry. At the forefront of biomimicry and airplane flight is the aerospace company Airbus. Airbus recently introduced the "Bird of Prey," the eagle-inspired conceptual airliner seen in the banner image.[10] The aircraft's wing and tail structure mimics the eagle's long broad wings. The Bird of Prey has individually controlled feathers––a step away from aerodynamically inefficient panels. Though the visionary design seen in Figure 3 does not represent an actual aircraft, it embodies industry's extensive research on bio-inspired aircraft designs. This appreciation of the results of millions of years of evolution will undoubtedly provide further inspiration for more maneuverable, aerodynamic, and efficient aircrafts.

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"Millions of years of bird evolution prove the same thing—the most efficient fliers use their wings as undivided bodies, not structures consisting of individually controlled flaps or ailerons."