THE WAY BIRDS FLY

Ever since man first became curious about his environment he has envied birds their ability to fly and has imagined learning their art, and freeing himself from his pedestrian limitations. The Greek myth of Daedalus and his son Icarus concerned the successful mastery of flight by these two mortals who devised wings to escape from Cretan captivity. But the contrivance was never repeated, perhaps because of the disastrous consequences to Icarus. Becoming overconfident, he flew so close to the sun that the wax by which his wings were attached melted and he crashed to his death--a punishment for his importunity in challenging the gods considered quite just by the Greeks. No explanation of how they managed their wings, which were copied from birds, feathers and all, was ever given. Nor were the mechanics of flight discussed in the Greek mythologies, either for these two experimenters or for the even less probable winged horse Pegasus. Apparently it was believed that equipment with wings was the only requirement for flight, and that once this was accomplished the manipulation of them would be self-evident. The gods flew about with the greatest of ease, but since they commanded magic powers their exploits, with or without wings, were taken for granted.

Later in the Christian era angels with wings made their appearance. Consideration of the efficacy of these appendages was probably irrelevant since angels, like Greek gods, had access to supernatural forces. Angels' wings seem to have served chiefly as a badge of status rather than as useful means of locomotion. Although they too were patterned after the birds and were proportionately a reasonable size, they could not have sustained flight without an adequate working mechanism which was not provided. In contem-

plating the Celestial Hierarchy above the angels the symbolic meaning of wings becomes increasingly evident as the top levels are approached where, if wings survived at all, they became vestigial.

Men have always dreamed of flying by the mastery of godlike powers to overcome the restrictions of gravity. Who in his sleep has not momentarily experienced the joys of a sudden acquisition of miraculous powers of flight, as well as the frustrations of their critical failure? Many schemes have been suggested in the past few hundred years to give men the freedom of birds. Some of the inventions were simple balloons subject to the vagaries of the wind, but from time to time machines with flapping wings in imitation of birds were proposed as means to surmount man's two-dimensional limitations. The most famous of these is undoubtedly the flying machine designed by Leonardo da Vinci in the fifteenth century. It had bird-like wings and conceivably might have flown, had it been built, since it depended for sustained flight on the approximately adequate leg muscles of the operator rather than, as in other devices, on his much too weak arms.

Not until the Wright brothers at Kitty Hawk separated the propelling power from the supporting wings was the feasibility of the flying machine demonstrated. Their success was assured not alone by abandoning the bird as a prototype but by the invention, in the gasoline engine, of a compact source of power. Except for a momentary return to a copy of the bird's wing in the German World War I Taube fighter plane, the design of airplanes turned away for good from an imitation of birds. Even an elementary analysis of the relations between weight, dimensions, and energy requirements for flapping flight would have made clear the inevitability of this course of technology. A flapping flying machine no larger than a small plane would not be able to carry an engine big enough to sustain useful flight; and

a machine the size of a jet liner would be a physical impossibility. That birds neither could indefinitely increase in size and still sustain flight would also have been demonstrated by the analysis. Probably physical limits for wing-flapping flight were reached in the largest extinct birds. The ostrich and the extinct moas are birds that exchanged the powers of flight for huge size as they adapted to purely terrestrial life, but it should not be assumed that massiveness is necessarily a parallel development with flightlessness, which results as well from other adaptations. But even among the larger flying birds the ability to remain air-borne for long periods of time was accomplished through special evolutionary developments. Some like the duck have developed pectoral muscles proportionately larger for their size than are found in less strong flyers. Others have adopted a soaring type of flight in which they depend on air currents more than on wing flapping to keep them aloft. Among these are some species that experience some difficulty in taking off on a windless day and must make a running start like an airplane to get off the ground. Needless to say, such a bird would be hopelessly trapped if it inadvertently landed in a forest. In fact cormorants, that rise from water by long flapping paddling runs on the surface, occasionally get caught in fish weirs from which they can escape only by diving under the nets.

How birds fly, the detailed elucidation of the mechanics of flight, was not even attempted until fairly recently and is not yet completely worked out. The process is very much more complex than the aerodynamics of the fixed wing soaring flight of gliders or motor-driven airplanes because birds' wings are jointed and designed for both soaring and flapping. In soaring the lift is obtained from rising air currents which the bird takes advantage of; in flapping he generates his own air currents. All birds flap their wings to some extent as in taking off, landing, or maintaining altitude on a still day, and some never soar or glide at

all. But even the soaring that birds do is more involved than the most sophisticated glider flight owing to the separate control they have over the segments of their wings. But by this very control flapping flight is still more complex and almost defies analysis. No generalizations on the relationship between the type of flight and wing anatomy are without exception. The wide stubby wings of quail are not always correlated with the rapid whirring flight characteristic of these birds, nor are narrow pointed wings always associated with the swift flight of the swallow. The problems of analysis arise from the number of variables involved. The wing of a bird has several planes which can be independently adjusted for lift and propulsion. Thus the proximal part of the wing next to the bird's body serves as an airfoil to support the weight of the bird; the end of the wing beyond the wrist where the primary feathers are attached can be separately moved to act as the principal propellor. These functions, however, overlap to varying degrees in different species. Some birds, the terns for example, move their wings stiffly, using the whole surface for both propulsion and weight support. The primary feathers play an important role too in determining the type of flight, but infallible relationships do not exist. The shape of the end of the wing is likewise an adaptation to important behavior requirements and environmental conditions. Narrow pointed overlapping primaries reduce eddies at the ends of the wings and allow a smooth flow of air which cuts down resistance. Separated primaries producing multiple slots for air to flow through at wing tip do the same thing. Although wide blunt wings with overlapping feathers, as occur in the owls and rails, are not usually associated with fast flight, whereas the rounded wings of the bird hawks, the accipiters, with primary feathers that separate, are correlated with strong, swift flight.

The way in which wing segments are manipulated to accomplish the kind