Birdflight and Aviation

An Unheralded View

by Lester D. Stephens

FROM THE TIME of the ancient Greeks men dreamed of flying like the birds, but most of the early observations of birdflight were general rather than specific, and none of them comprehended the aerodynamical principles involved. Fanciful notions finally began to give way when the great Leonardo da Vinci wrote his thoughtful treatise *Sul Volo degli Uccolli* in 1505. Leonardo failed to solve "the problem of bird propulsion,"[1] however, and, even though later thinkers addressed themselves to the subject of birdflight as a basis for developing a manned airship, the next serious studies of the topic were not published until the 1870s, when the Englishman J. Bell Pettigrew and the Frenchman E.J. Marey issued their respective books on *Animal Locomotion* and *La Machine Animale* (translated into English in 1873 as *Animal Mechanism*).[2] While both of these works contained special sections on birdflight and aeronautics, Marey's was the more influential.

Meanwhile, a young German named Otto Lilienthal was busily engaged in a serious and profoundly meticulous study of birdflight, and in 1889 he published the results of his remarkable observations as *Der Vogelflug als Grundlage der Fliegekunst* (translated into English in 1911 as *Birdflight as the Basis of Aviation*). Lilienthal, who later built several successful gliders before sustaining a fatal accident in his last one, began his study of birdflight as a boy, and by the late 1860s he was already conducting experiments related to air pressure and the beating of bird wings in rising and propelling. His magnificent treatise on birdflight contained astute observations, reports of carefully conducted experiments, and mathematical calculations regarding bird locomotion.[3]

Historians of aviation have acknowledged the contributions of Marey and especially Lilienthal to the study of birdflight as a basis for a manned aircraft, but they have generally ignored the

thoughtful observations of other writers who published serious studies of birdflight. Among those who deserve at least a modicum of credit for his careful analysis of the locomotion of birds in the air was Joseph Le Conte (1823-1901). Born and reared on a south Georgia rice and cotton plantation, Le Conte was educated at the University of Georgia, from which he was graduated with honors in 1841. In 1845 Le Conte completed his studies for the doctor of medicine degree at the College of Physicians and Surgeons in New York. After a brief practice in Macon, Georgia, Le Conte went to Harvard University to study under the famous Swiss scientist Louis Agassiz. Upon completing his work there he returned to Georgia and taught at his alma mater from 1852-1856 and then took a position at the College (later University) of South Carolina. In 1869 he and his older brother John, a physicist, moved to the West Coast where they became professors at the newly founded University of California. Joseph Le Conte distinguished himself there as an outstanding geologist, philosopher, and proponent of the theory of evolution. When he died in 1901, he had gained an international reputation for his work in geology, physiological optics, biology, and philosophy and religion. Little known, however, are his ornithological studies and his thoughts on the topic of birdflight applied to the principles of aeronautics.[4]

Joseph Conte (1828-1901) photo circa 1885.

During his youth and young manhood Le Conte spent a considerable amount of time in collecting specimens and observing bird behavior, including birds in flight. After he donated his large collection of specimens to the United States National Museum in 1858, he devoted less attention to the study of avifauna, being occupied fully with other interests.[5] He continued to observe birds throughout the remainder of his long life, however, and in 1888 he found time to write a paper on the topic of the principles of birdflight as related to a flying machine. Then, in 1894, he published a second paper on the subject. Both of these papers appeared in *Popular Science Monthly*, which was at the time a highly respectable medium for scholars writing on popular scientific subjects.[6]

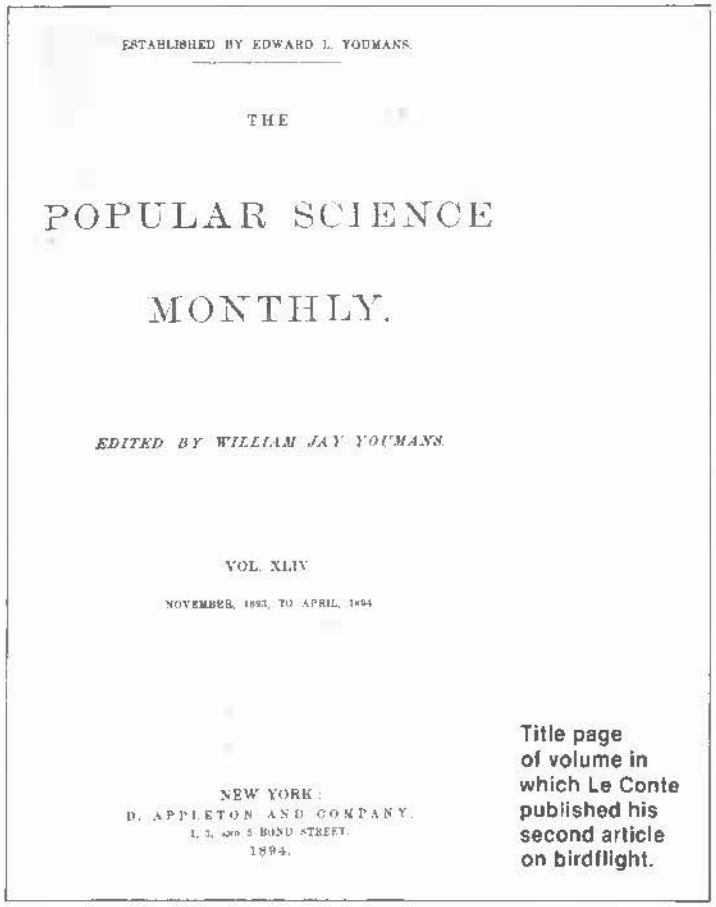
Le Conte wrote his first article, "The Problem of a Flying Machine," in response to a paper on the same subject by T. W. Mather in 1885.[7] Mather, an engineer, had expressed great optimism about the possibilities of developing a flying machine. He noted the aerodynamic difficulties which had to be overcome, but he concluded that while "the results [of current studies] are far from encouraging . . . still there are the birds; they completely refute the argument of those who say 'It is impossible to build a successful flying-machine.'" Le Conte read the article, and as soon as time permitted him to deviate from his teaching duties and his numerous writing projects, he drafted a response to Mather's optimistic conclusion. "Now, I wish to take issue with Mr. Mather in this conclusion," he said, for "I am one of those who think that a flying-machine, in the sense indicated above—i.e., self-raising, self-propelling—is impossible, in spite of the testimony of the birds."[8]

To prove his point, Le Conte set forth a number of propositions which he believed would demonstrate the impossibility of constructing a successful manned airship. But first he prefaced his remarks with a comment on the necessity of being aware of "two kinds of impossible—the *seeming* and the *real*."[9] The first of these, he declared, deals with phenomena about which "we do not yet understand the principles involved" but which when apprehended become possible. The second, he averred, deals with problems which cannot be resolved because "we *know* . . . [and] see clearly through all the principles involved . . . and [therefore understand] the *limits* of their application." In the latter category he placed the problem of building a workable aircraft. He argued that such was *really* impossible, primarily because the necessary weight of such a vehicle must exceed the strength of the materials from which it would be constructed, and the sheer size of the machine would go against aerodynamic principles. Based upon his observations and calculations, then, he declared that there are limits to the size of animals which can walk and to birds which can fly. Drawing upon natural history and the theory of evolution, therefore, he pointed out that "the huge dinosaurs of the Jurassic period" had reached the limits of weight and size in regard to locomotion, and the large flightless birds "such as the ostrich, the emu, and especially the extinct *Dinornis* and *Epiornis*" had exceeded the point beyond which they could lift themselves into sustained flight. This was so, he argued, because "as the animal increases in size, its *weight* increases as its volume or as the cube, while the strength of bones and muscles increases only as the cross-section or as the square of the diameter." It must be recognized, he continued, that "there is a limit of size and weight of a flying animal; and on account of the prodigious energy required for aerial locomotion *that limit is very low, not much more than fifty pounds, certainly much less than one hundred pounds.*" Hence, he concluded, since a manned flying machine must necessarily exceed that weight, it could never succeed.

But Le Conte contended that additional problems served as obstacles to flying, of which those of life and propulsion and the amount of energy consumed were the most serious. On the first point, he noted that "the *difficulty of rising in*creases as the size or weight . . . [while] the resistance of the air to motion through it and therefore the *difficulty of propulsion* of a flying animal *de*creases in the same ratio." Thus, he explained, "large birds like the condor rise with difficulty; but once up they sail with ease and grace, while small birds and insects rise with ease, but require rapid and incessant fluttering in progressing." To the contemporary arguments that new sources of power could allay the problem experienced by birds in rising and propelling themselves, Le Conte countered that advocates of this view overlooked the fact that such sources were characterized by "*intensity*" of force and not by "*quantity*." In other words, these fuels might be sufficient to propel an aircraft, but they had to be present in such large quantities that they would make the machine too heavy for flight.

If this had been the end of Le Conte's views on the development of a flying machine, then he could be dismissed as just another of those intractable critics who always resist new ideas. But such was not the case, for Le Conte was neither an inflexible person nor an individual who could not admit his mistakes in the face of new evidence. In fact, he must surely have been forced to begin re-thinking his views immediately when Mather responded to his argument shortly after Le Conte's pessimistic article appeared in print.[10] "I can not admit," said Mather, "that his [Le Conte's] premises warrant his very discouraging conclusions." In fact, Mather confronted Le Conte on his own ground, that is, on the principles of bird propulsion. By mathematical formula and by reference to knowledge regarding machines, Mather clearly demonstrated that Le Conte's argument contained several flaws. Le Conte, as Mather indicated, had overextended the analogies of bird-energy to mechanical power. Moreover, as Mather explained, Le Conte had drawn limits on the size of nature's walking machine (i.e., the dinosaur), but he had ignored the fact that man had constructed highly successful, 80-ton locomotives. Likewise, Le Conte had argued that the whale represented nature's limit on the size of a water-propelling animal, but, as Mather reminded him, he failed to acknowledge that "our ocean-steamers, indicating fifteen thousand horse-power" ply the seas with phenomenal ease. Said Mather, "I can not help thinking Prof. Le Conte at fault in placing . . . [the problem of flying] among the 'impossibles'."[11]

There is no evidence to suggest that Le Conte responded to Mather, but in light of the substance of his second article on the topic of flying, it is reasonable to assume that Le Conte was struck by the thoughtful points raised by Mather. At any rate, Le Conte's serious attention to the problem of flying drew many comments, and it was sufficient to earn him an invitation to prepare a paper for the International Conference on Aerial Navigation to be held in Chicago in August 1893.[12] Since the publication of his original article on aviation, Le Conte had also been impressed by S.P. Langley's fruitful experiments on flying.[13] Thus challenged by Mather and influenced by Langley, Le Conte was, in his own words, "forced to reconsider and modify somewhat the conclusions" he had reached in his earlier paper. Other duties prevented him from completing his address for the International Conference but eventually he drafted an article for the *Popular Science Monthly*, setting forth his revised views on bird-flight and the construction of a flying machine.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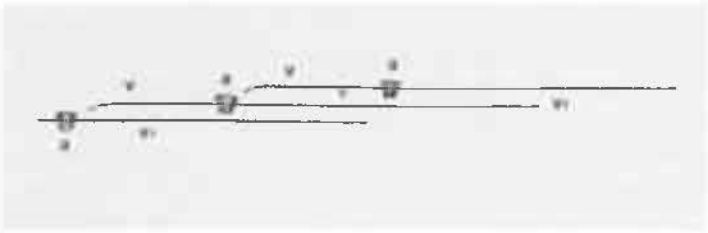
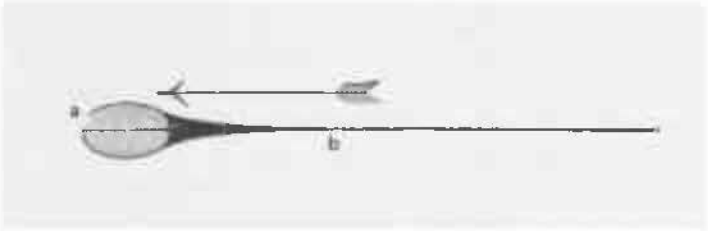
Title page of volume in which Le Conte published his second article on birdflight.

In his second article Le Conte dealt with two topics, namely, the bird wing as a propeller and as an aeroplane, or, that is, with the qualities of lifting and sustaining in flight. The first of these he treated rather cursorily, for he believed "it is in the use of the wing and an aeroplane that the most wonderful feats of bird locomotion consist," and therefore that the principles of the latter were more crucial "if we are ever to achieve artificial flight."[14] Nevertheless, after admitting that he had previously failed to "appreciate the supreme importance" of the bird's wing as a propeller, he addressed himself to two points. First, he noted that the "hinder" of the two feather vanes is always broader than the former. That fact, taken together with "the manner of overlap" of the feathers, results in a rotation of the feathers and a closure which creates "an impervious plane" in downward motion and an opening up in the opposite direction, thereby producing maximum effectiveness. Then, Le Conte observed that "the plane of the wing is supported not along the middle, but along the extreme anterior border. . . ." In a downstroke the wing would thus tip upward at the posteriot extremity. Hence, the force of each stroke would not only propel the bird forward but also act to sustain its flight. To illustrate his points Le Conte included three remarkably detailed and clear diagrammatic representations of the bird's wing.

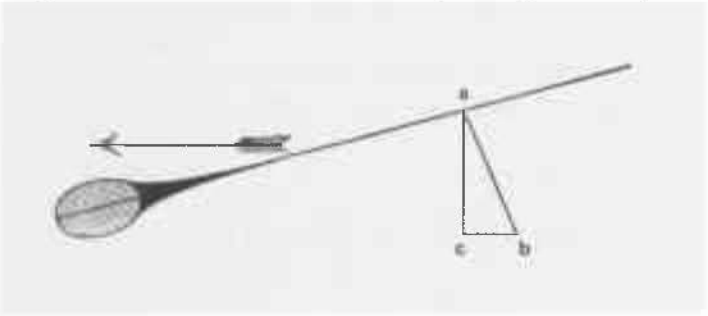
On the subject of the wing as an aeroplane, Le Conte offered a more elaborate commentary. He identified four distinct phenomena or "feats" of birdflight: hovering, poising, soaring, and sailing. In each case he gave examples of particular species which were capable of performing the individual phenomenon,



Longitudinal section of the wing plane and cross-section of three feathers; *a*, shaft; *v*, v_1, vane.



Diagrammatic cross-section of bird's wing; *a*, wing bones; *b*, plane.



Diagrammatic cross-section of bird's wing during downstroke; *a*, *b*, whole force; *a*, *c*, part sustaining; *b*, *c*, part propelling.

and in every instance these were drawn from his own observations. Additionally, he cited the special characteristics related to the aerodynamic process involved in every instance.

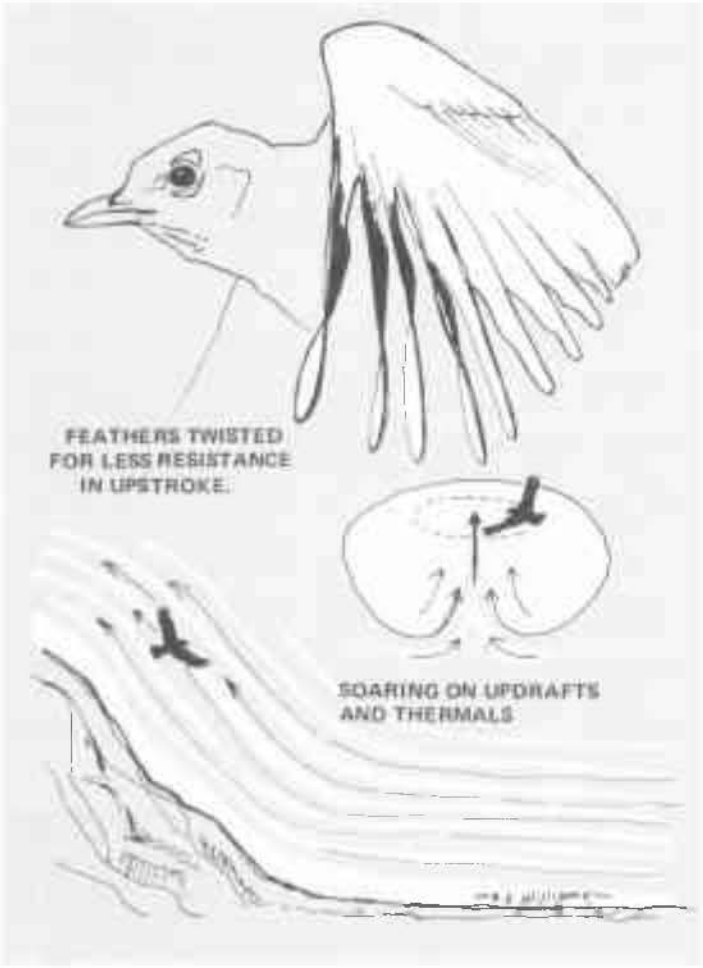
Hovering birds, said Le Conte, include the hummingbird, the sparrow hawk, and the osprey—all of which he had observed in his native region of south Georgia. Le Conte noted that since the "downward stroke gives onward motion," each of these species inclines its body upward and flaps its wings both forward and downward. Hence a downward current is created by each wingstroke, causing displacement of the air. This results in "hovering" rather than in forward motion. To achieve the latter, the bird must rectify the position, and its wings must pass on "to new, unmoved air."

Le Conte defined "poising" as "the maintenance of a fixed position with outstretched, motionless wings." As an example of a species capable of that feat, he cited the red-tailed hawk, which he had observed on several occasions during excursions into eastern Oregon. Le Conte explained that poising was possible only in "rolling country" because the bird fixes itself over the edge of a hill and faces the wind. As the wind is naturally deflected upward there, the bird slightly inclines its wings and tail downward and catches the wind on their under surface. Thus utilizing its wings as an aeroplane and the force of gravity to pull its body downward, "the bird skillfully adjusts" the plane and thereby balances the two forces.

The phenomena of soaring and sailing Le Conte considered to be especially pertinent to the development of an aircraft. He defined "soaring" as the ability of a bird to "sweep about in wide circles with motionless, outstretched wings," and he named the vulture, the hawk, and the pelican as good examples of birds possessing that ability. Le Conte stated that no other problems of birdflight had received as much comment as that of soaring, but he likewise contended that most of what had been published on the subject was worthless. He therefore offered a fairly detailed explanation of the phenomenon. In essence, he argued that wind is the crucial factor, for "indeed, a soaring bird always drifts with the wind," and it always spirals slightly to leeward and never absolutely upright. Such birds, he noted, take advantage of "differential currents" of air. The bird senses the "invisible differential currents, and skillfully uses them to lift himself." Admitting that he had only recently come to comprehend this phenomenon, Le Conte acknowledged that Langley's aerodynamic experiments had been helpful to him, and he confessed that such knowledge had in part caused him to retract his former statement regarding the possibility of developing a workable flying machine.

The final form of birdflight Le Conte called "sailing," and he listed the albatross and the gull as examples of birds capable of this feat. On several voyages along the Pacific Ocean he had carefully observed those creatures following the ship on which he was a passenger. Especially intrigued by the albatross, Le Conte sought to explain its actions of "skimming the surface of the sea, then rising and wheeling and swooping, and again skimming, but without moving a feather for hours." As with the soaring birds, said Le Conte, the albatross "takes advantage of the great difference of velocity between the lower and upper strata of the air." Moreover, he noted that the bird also utilizes air currents created by head winds and "eddies in the wake of the boat." In other words, the albatross sails in spiraling evolutions, rising against the air flow and then swooping down with the current. It thereby uses its wings as a glider and makes flapping unnecessary.

After these reflective observations, Le Conte took up the "fallacies" of his previous paper. He acknowledged that he had not conceived of separating the propelling and gliding functions, and now, in the light of new developments, he agreed that the two functions could be accomplished in distinct operations. Regarding the consumption of energy and the strength of materials for an aircraft he admitted that he had underestimated



both, although he continued to believe that the total weight limit would have to be low (i.e., it "may be pushed to several hundred pounds" but not beyond). The most significant error, however, he confessed to be his failure to realize "the effect of motion on the sustained power of an aeroplane." Langley's experiments had clearly demonstrated to Le Conte "that in air a body does not fall the same distance in a given time whether it falls straight downward from rest or is affected with horizontal motion." Now, conceded Le Conte, if a flying machine could be gotten "well up in the air and moving onward . . . there seems to be no physical impossibility of sustaining it indefinitely and giving it by means of suitable propellers a great velocity, say of forty to sixty miles per hour." Thus, said the esteemed scientist, while the difficulties of constructing a successful airship would be enormous, they could possibly be overcome.

Le Conte was obviously unfamiliar with Lilienthal's book on birdflight; it had not then been translated into English, and it had not yet received the wide acclaim it deserved. He was certainly aware of Marey's work—and perhaps even with Pettigrew's little volume on the subject of animal locomotion and birdflight. But neither of the latter fully comprehended some of the principles described by Le Conte. Thus, Le Conte entered an increasing company of thinkers in the 1890s who published thoughtful remarks on the principles of bird locomotion as related to the aerodynamic problems of a flying machine. His early skepticism reflected the general pessimism of most of his contemporaries but his remarkable knowledge of birds and his open attitude toward new evidence led him to modify his position and become one of the first in his own country to address the subject from a scientific point of view. Certainly, his understanding of physics, aerodynamics, and engineering was limited, but LeConte displayed a knowledge of birdflight that far exceeded that of most of his peers. He did not contribute directly to the development of an aircraft, nor is it even likely that the Wright brothers took notice of his observations in their study of the literature on aeronautics. Nevertheless, he showed the kind of curiosity, knowledge, and interest which helped place the problem in perspective, and thus he deserves to be recognized for his reflective comments on a subject which was eventually to revolutionize transportation and to alter the course of modern history.

NOTES AND REFERENCES

1. Charles Harvard Gibbs-Smith, *Aviation: An Historical Survey* (London Her Majesty's Stationery Office, 1970), pp. 8-9.
2. J. Bell Pettigrew, *Animal Locomotion* (New York: D. Appleton, 1873; reprinted 1893); see pp. 103-206. E.J. Marey, *Animal Mechanism*, (New York: D. Appleton, 1874); see especially pp. 209-78. Gibbs-Smith, *Aviation*, gives a brief assessment of the theories of Marey and Pettigrew, p. 48. For an indication of the extent of published commentaries on birdflight, see Paul Brockett, *Bibliography of Aeronautics*, (Washington, D.C.: Smithsonian Institution, 1910), which lists more than 200 articles on that topic alone.
3. Otto Lilienthal, *Birdflight as the Basis of Aviation*, (London: Longmans Green & Co., 1911). Lilienthal wrote numerous articles on his experimental gliding flights; see, for example, those published in James Mean's *Aeronautical Annual*, 3 vols. (Boston: W.B. Clarke & Co., 1895-97). An excellent assessment of Lilienthal's work is given in Gibbs-Smith, *Aviation*, 72-80.
4. The information on Le Conte is taken from his *Autobiography* (New York: D. Appleton, 1903), and from various letters in public and private archives (cited in several articles on Le Conte by the author).
5. See Lester D. Stephens, "Joseph Le Conte's Contribution to American Ornithology," *Georgia Journal of Science*, 35 (June 1977), 170-81.
6. These appeared in *Popular Science Monthly* in November 1888 (pp. 69-76) and April 1894 (pp. 744-57), respectively.
7. T.W. Mather, "Flying-Machines," *Popular Science Monthly*, 28 (November 1885), 1-18.
8. *Ibid.*, p. 1.
9. This and subsequent quotations come from Le Conte's "The Problem of a Flying Machine," op. cit.
10. Mather, letter to the editor, *Popular Science Monthly*, 34 (February 1889), 556-57.
11. *Ibid.*
12. For a report of the conference program, see *Aeronautics*, 1 (October 1893), pp. 2-3. Many of the papers were published in subsequent issues of that journal, which was originally a part of the *American Engineer and Railroad Journal*.
13. See, for example, Langley's *The Internal Work of the Wind* (Washington, D.C.: The Smithsonian Institution, 1893), and his earlier volume, *Experiments in Aerodynamics*. Smithsonian Contributions to knowledge, vol. 27 (No. 801, Smithsonian Institution Series, 1891).
14. This and subsequent quotations are taken from Le Conte's "New Lights on the Problem of Flying," *Popular Science Monthly*, 44 (April 1894), 744-57.

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Lester D. Stephens is Professor of History at the University of Georgia. He received his Ph.D. degree from the University of Miami in 1964. Author of two books and co-author of two others, he has published over twenty articles. Currently, Professor Stephens is working on a biography of the nineteenth-century scientist Joseph Le Conte.