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Nature's lessons in aero-design

Nature's master flyers have been simulated on the computer, says S.Ananthanarayanan.

The ability to fly has always fascinated. From mythological figures, like fairies, to the legendary Icarus, who rose into the sky with wings that his inventor father fashioned for him, the imagination of man has tried to imitate the birds, which defy gravity and master the sky.

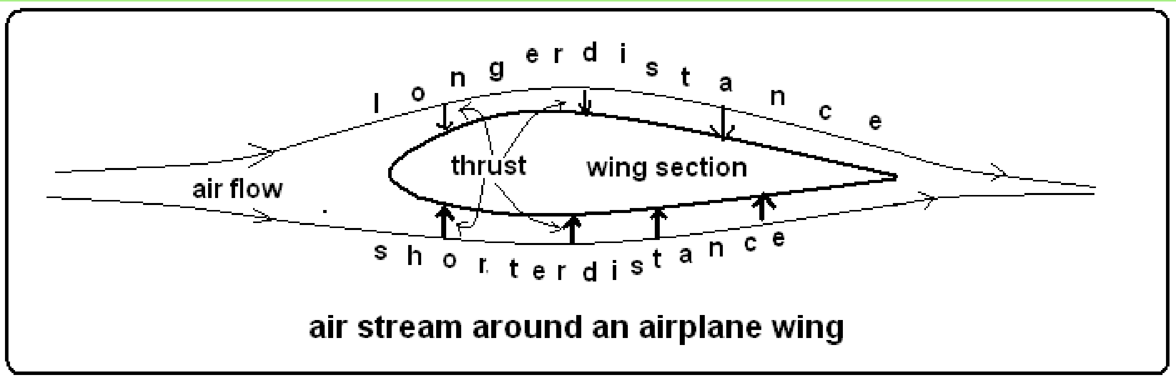
The first scientific thinker about artificial flight was Leonardo da Vinci, who made drawings of flying machines, but which were more imaginative than functional. The Wright brothers, over a century ago, were able to perfect a device with wings and propeller, which could actually speed up on the ground, rise into the air and stay airborne! The sequel is history.

And yet, when it comes to mastery of control in flight and the economy of the energy used, technology is nowhere near the perfection that nature is able to reach. For all the physics and fluid dynamics and jet propulsion and what else, engineers still wonder at the way living things, birds and insects, like locusts and bees, are able to manoeuvre and fly long distances. The locust, for instance, is able to cross the Atlantic without a refuel stop!

Researchers in the University of New South Wales, Australia and the University of Cambridge, with high speed digital video shots of locusts in flight, seem to have opened a crack to peep into the mystery of how nature does it!

Bumblebee paradox

Flight of a heavier than air object, like an airplane wing, is explained by the action of air flowing smoothly around the profile of the wing, which is shaped so that the upper edge is longer round than the lower edge. Science says that because the air above the wing has to move faster, to reach the other end, it does not press down upon the wing as hard as the air below the wing, which is moving slower. The result is that there is a net upward push, which keeps the wing aloft.

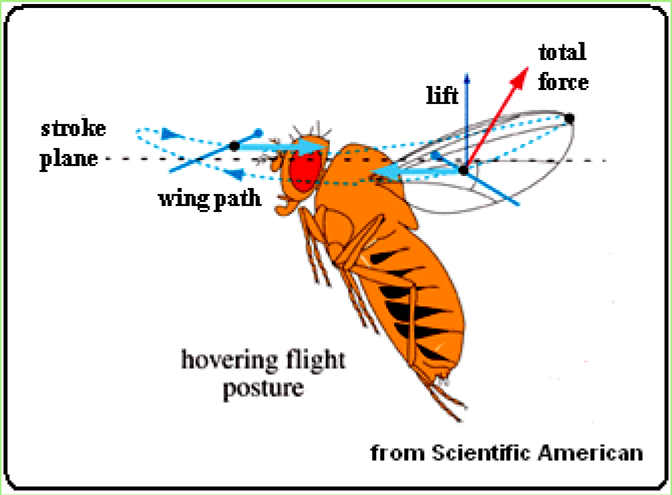


The theory is exact and simple so long as we are talking about air that moves ***smoothly*** around the wing. If the wing were to move very fast through the air, the relative movement would not be smooth, but would become turbulent, with whorls, eddies and uneven pressure distribution, which complicates things. The sensitive control that living things, like birds and insects, can exercise over flight seems to come from control of these complex features of fluid dynamics.

During the last century, scientists have looked hard at the flight of insects, the structure of their wings, how strong their muscles are, the nature of the down stroke and the up stroke, and so on. The result, of calculations in the University of Gottingen in the 1930s, was that flight of the bumblebee, by the principles of aerodynamics, was not possible! But, as the title of the children’s book by Robert Cormier says, “The Bumblebee Flies Anyway!”

Cambridge and Berkley

In 1996, the Department of Zoology in the University of Cambridge built larger scale models of insects and their wings to study the airflow when the insects were in flight. Animal Mechanics specialist, Charlie Ellington and his team managed to work it out that although in the way the airplane or helicopter wing was built, the insect was not equipped to fly, the deficiency in lift was made good by a vortex that traveled along the foremost edge of the insects’ wings when the wings were flapping down. It seemed an answer had been found to the theoretical difficulty that the Gottingen group had posed.



But scientists from the California Institute of Technology at Berkley performed experiments with an enlarged model of the fruit fly placed in flowing mineral oil, and published in the journal, ***Nature*** that reality appeared to differ from the explanation by the University of Cambridge. Placing a large size model of the insect in a carefully selected, heavy medium, like the oil, simulated the real aerodynamics of the tiny insect in the air – and could show that science still had not got a handle on how the insect did it. "We didn't really know how the damn things could stay in the air," Michael Dickinson, the leader of the Berkley group said.

Digital Videography

The University of Cambridge did not give up but kept at it and, along with Dr John Young of UNSW, they videotaped the wings of the locust as it flew in a wind tunnel. There was no large scale model, no compensated flight medium, but the real locust in air. The main difference was high tech, high resolution, high speed photography.

The results, as just reported in the journal, ***Science***, were detailed pictures of the locusts' wings as they deformed and adjusted shape for sensitive control of the flight path. The data was then sufficient to program a computer to simulate locust wings, which would recreate the complex flapping motion to generate the airflow and thrust that supports the flying insect.

The locust is of interest because it is perhaps nature's master of flight, for the energy economy of its wing action, which enables it to cover incredible distances with meager nutrition. Understanding how its wing stroke and wing profile are optimized would help design comparable artificial flying devices, comparable both in size and in agility, for rescue or military operations, or work within hostile environments, like underwater, in furnaces, in inflammable or explosive gases, to defuse bombs, etc.

"An insect's delicately structured wings, with their twists and curves, and ridged and wrinkled surfaces, are about as far away as you can get from the streamlined wing of an aircraft," Dr Young said.

"Until very recently it hasn't been possible to measure the actual shape of an insect's wings in flight – partly because their wings flap so fast, and partly because their shape is so complicated.

"The message for engineers working to build insect-like micro-air vehicles is that the high lift of insect wings may be relatively easy to achieve, but that if the aim is to achieve efficiency of the sort that enables inter-continental flight in locusts, then the details of deforming wing design are critical," Dr Young said.