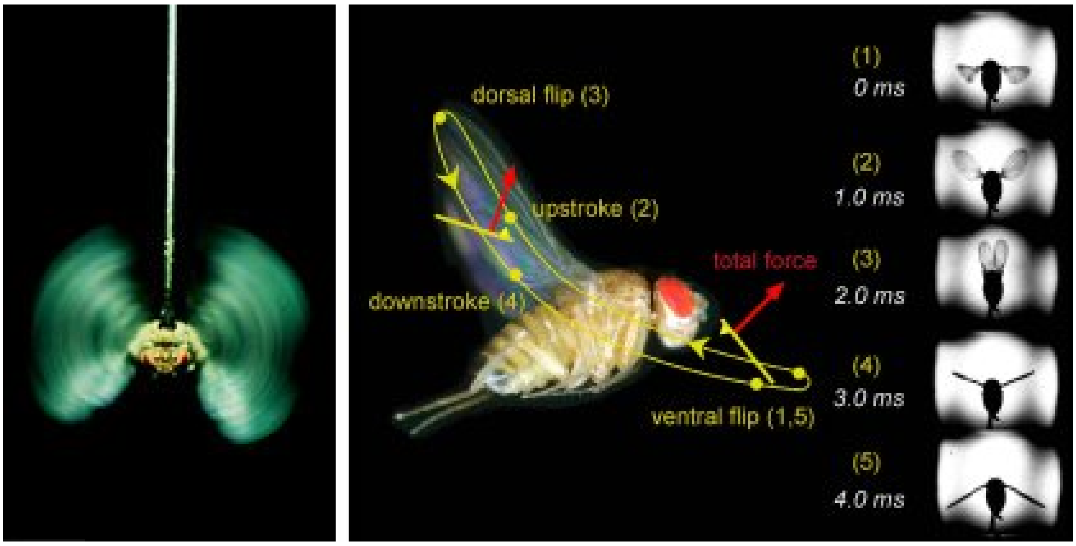
Uni Ulm Search

Aerodynamic Flight Mechanisms

Introduction

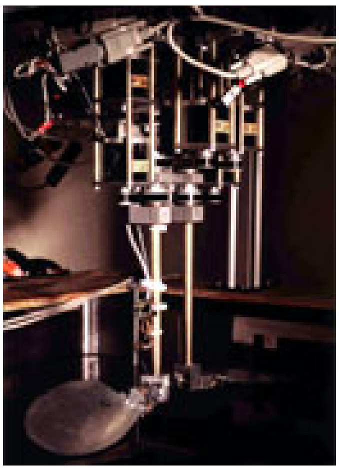
The BMBF research group in the [Department of Neurobiology] at Ulm University aims to develop a comprehensive understanding of the function, energetic efficiency and evolution of invertebrate aeromechanics. Using an integrative approach where the biophysical bases of the flight system, theoretical flight models and biological mechanisms for the production of locomotor forces are examined. The goal of the research is to produce a comprehensive theory for the various forms of insect flight.



Movement phases of the wings of a fruit fly *Drosophila*. (Fig. Copyright Michael Springer/Gamma Liaison)

Aerodynamic limits of animal flight

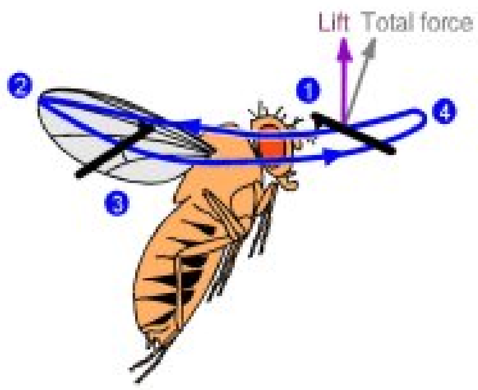
The traditional aerodynamic approach to animal flight follows the conceptual framework used for aeroplane wings, which travel through the air at a steady speed and with constant orientation. Under such steady conditions a flow pattern is formed around the wings that has a constant strength and direction over time and therefore is suited to analysis in a wind tunnel. For the fast forward flight of animals such as bats or birds this steady viewpoint supplies plausible results, since the wings experience a continuous high speed flow due the forward movement of the body. For small animals such as insects the flight force production under steady conditions explains only a small part of the high total aerodynamic force required; the forward flight speed of these animals only amounts to a fraction of the beating wing's speed. The discrepancy between the lift forces of an insect wing fixed in a wind tunnel and of a wing actively moved through a kinematic cycle has, for the past 40 years, driven the search for the aerodynamic phenomena that can account for the high flight force production of animal flapping flight.

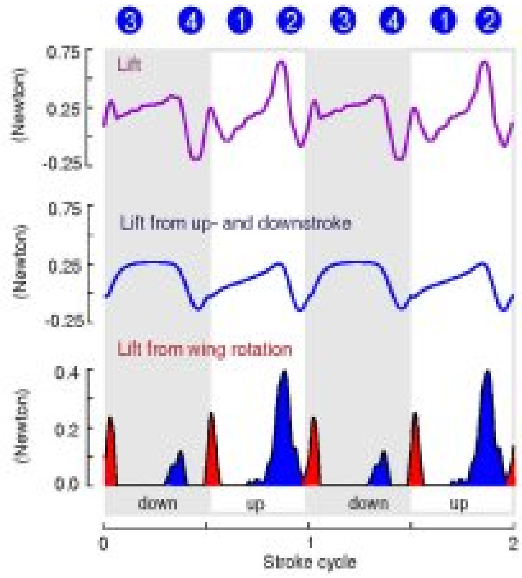


Mechanics of the robot fly. A robot fly was designed to analyse insect aerodynamic force production. From the wing movements of a flying insects, a computer generates instructions to control six stepper motors simultaneous to enable replication of the insect wingbeat kinematics. Three of these motors control the movements of each robot wing. The compact wing joint converts the movement of two stepper motors into up/down and backwards/forwards motion. A third stepper motor rotates the wing around its longitudinal axis. A force sensor mounted directly to the wing joint registers forces parallel and perpendicular to the wing surface.

Insights gained by the Robot model

In autumn 1999 the research group, in co-operation with M. Dickinson (CalTech, the USA) and S. Sane (Seattle, the USA), succeeded in discovering a new aerodynamic phenomena in flying insects. At the beginning of this research a dynamic-scaled mechanical robot was developed to model the 1,0 mg fruit fly *Drosophila*. Electronically steered wing movements made it possible to examine different kinematics of the insect wings. The significance of the different phases of the wingbeat cycle for the production of locomotor forces could be investigated by the simultaneous recording of aerodynamic force production and flow patterns, for the first time. The power generated in flight takes place via 3 interactive fluid dynamic processes: (1) the development of a vortex bubble on the upper surface of wing in the up and down strokes, (2) the initiation of flow circulation around the wing by wing rotation and (3) "energy recycling" at the points of wingbeat reversal when the wing changes its direction of motion. The discovery of these mechanisms prove a solution to the biological aerodynamic conundrum that significantly furthers the development of flying miniature robots, whose propulsion principles are likely to be shared with those of insects.





The wing movements of the fruit fly produces aerodynamic lift forces, which consist of forces generated during the up and down stroke and forces developed during the rotation of the wing.
Fig. left: The movement phases: 1 = wing translation (up stroke), 2 = wing rotation (pronation), 3 = wing translation (down stroke), 4 = wing rotation (supination). The black triangle at the wing leading edge indicates the upper side of wing.
Fig. right: The lift forces during two beat phases: Blue surface = lift force generated by wing rotation, red surface = lift force generated by "energy recycling".

Energetic limits of the flight system

The high power gain of beating wings requires efficient flight muscles, which can cope with the high power requirement of the aeromechanic mechanisms in flight. The simultaneous use of micro respirometry methods to measure flight metabolic rate and behaviour analyses in a 'virtual reality' flight simulators, makes it possible to directly quantify vital muscle-physiological processes and parameters such as the mechanical power reserve and the efficiency of muscle fibres in the flying animal. By deliberate elimination of individual muscle proteins in fruit fly (*Drosophila*) - genetic mutants can be used to assess the impact of individual structures on flight muscle efficiency and their influence on the overall evolution of the flight system.

Current research projects

Research projects of the BioFuture group are currently:

- Development of the second generation of dynamic-scaled flight robots,
- Development of concepts and models for flight stabilisation and for the manoeuvrability of flying animals,
- Energetic evaluation of aerodynamic processes in robots and insects.
- Neuromuscular bases for the control of aerodynamic forces in insects.

For further infomation on current research projects go to our current projects page.

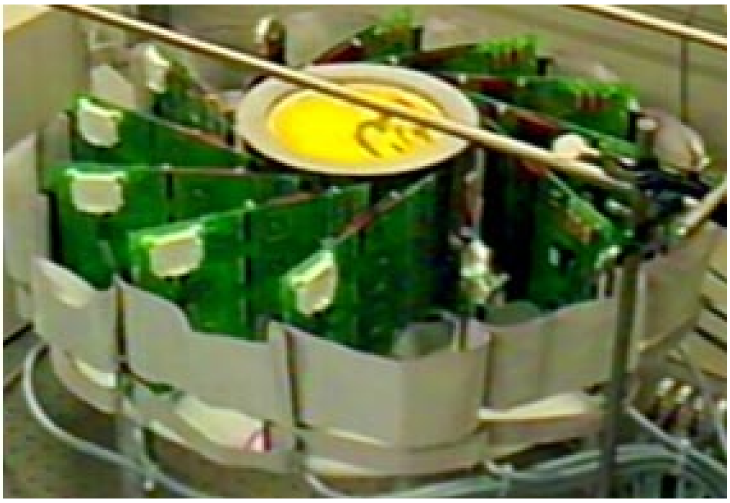


Fig. left: Respirometry chamber to measure flight forces and metabolic rates in the fruit fly *Drosophila*.
Fig. right: 'Virtual reality' - flight simulator for insects

Contact	Dept. Neurobiology BioFuture Research Group Project Leader: Dr. Fritz-Olaf Lehmann Co-workers: Dr. William Maybury, Nicole Heymann BioFuture Research Group Email: fritz.lehmann@biologie.uni-ulm.de Tel: +49 (0)731 502 3122
Home	BioFuture Research Group Home Page
Vacancies	Post-Doctoral Fellow (Bat IIa), immediate

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Technical questions to Will.Maybury@biologie.uni-ulm.de
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