Biology 427 Biomechanics Lift and circulation

- •Recap drag, shape, and the Reynolds number
- Return to lift and Bernoulli
- History of flight
- Basic definitions of wing shape
- The relationship between lift and circulation
- •Mechanisms that promote or maintain circulation



Back to Bernoulli and lift: and a caution

$$(P_2 - P_1)/\rho = (u_1^2 - u_2^2)/2$$





But first a bit of history and motivation!





Aristotle 350 bce

"...there must be something immoveable ... upon which that which is moved moves. For were something to give way advance would be impossible, and neither would there be any walking unless the ground were to remain still, nor any flying or swimming were not the air and the sea to resist"

"In birds the arms or forelegs are replaced by a pair of wings... For it is part of the bird that shall be able to fly and by the extension of wings this is made possible"



Leonardo da Vinci ~1500

"what quality of air surround birds in flight? The air surrounding the bird is above thinner than the usual thinness of the other air, as below it is thicker than the same... in proportion to the velocity of the bird in its motion forward ..."

Sul volo degli Uccelli (On the flight of birds) Leonardo da Vinci ~1500





Giovanni Borelli 1680

Johan Bernoulli



TAB XIII







Johan Bernoulli





concerning the strength of the work and movements of the fluids







Otto Lilienthal 1839



Étienne-Jules Marey 1882







"The flying machine which will really fly might be evolved by the combined and continuous efforts of mathematicians and mechanicians in from one million to ten million years" The New York Times, 9 October, 1903 "We started assembly today" Orville Wright's Diary 9 October 1903











Lift and circulation



Lift and circulation

With the mean subtracted, there is an effective circulation (Γ) about the wing. Greater Γ implies a greater velocity difference





 $\Gamma = U c sin(\alpha)$ Message: lift can be measured by the amount $L' = \rho$ $U \Gamma$ of circulation held by a wingCirculation is conserved (Kelvin's circulation theorem)For everyclockwise spin there is a counter clockwise one elsewhere in thefluid.





What aspects of a wing influence circulation?



Aspect Ratio = Span²/AREA



Message: lift can be measured by the amount of circulation held by a wing Higher aspect ratio wings loose proportionately less



Circulation can be lost from the wing as a tip vortex

http://www.petersononline.com/birds/perspective/flight.html



Increasing aspect ratio-

Limits to aspect ratio? Structural, flight mode ...

http://lautaro.fb10.tu-berlin.de/user/michaels/michaels_eng.html





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Let's look at the NASA's tool for understanding this.



For real wings in real fluids, we cannot ignore viscosity and the finite span of the wings.



Real wings have drag as well.

Two kinds of drag (profile drag and induced drag). Both depend on shape (A_R , camber), Re, angle of attack





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