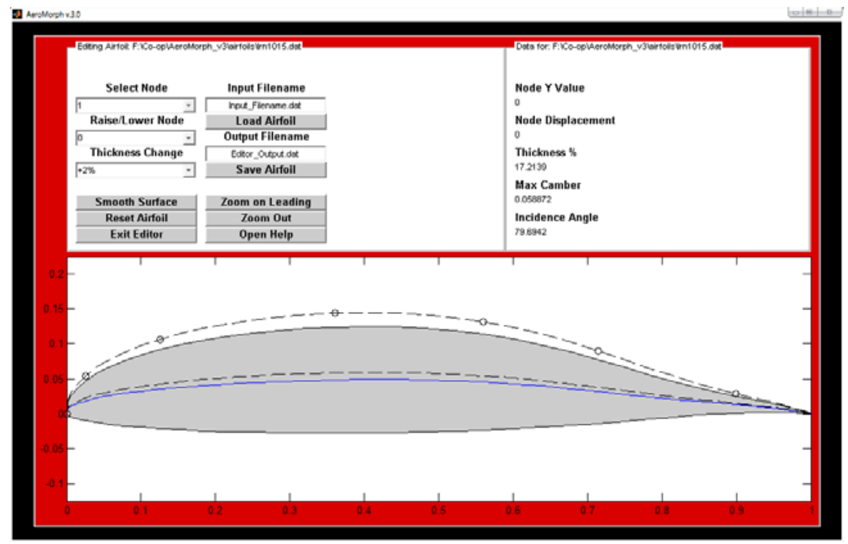
Bio-Inspired Flight



Faculty Mentor: Associate Prof. Kelly Cohen
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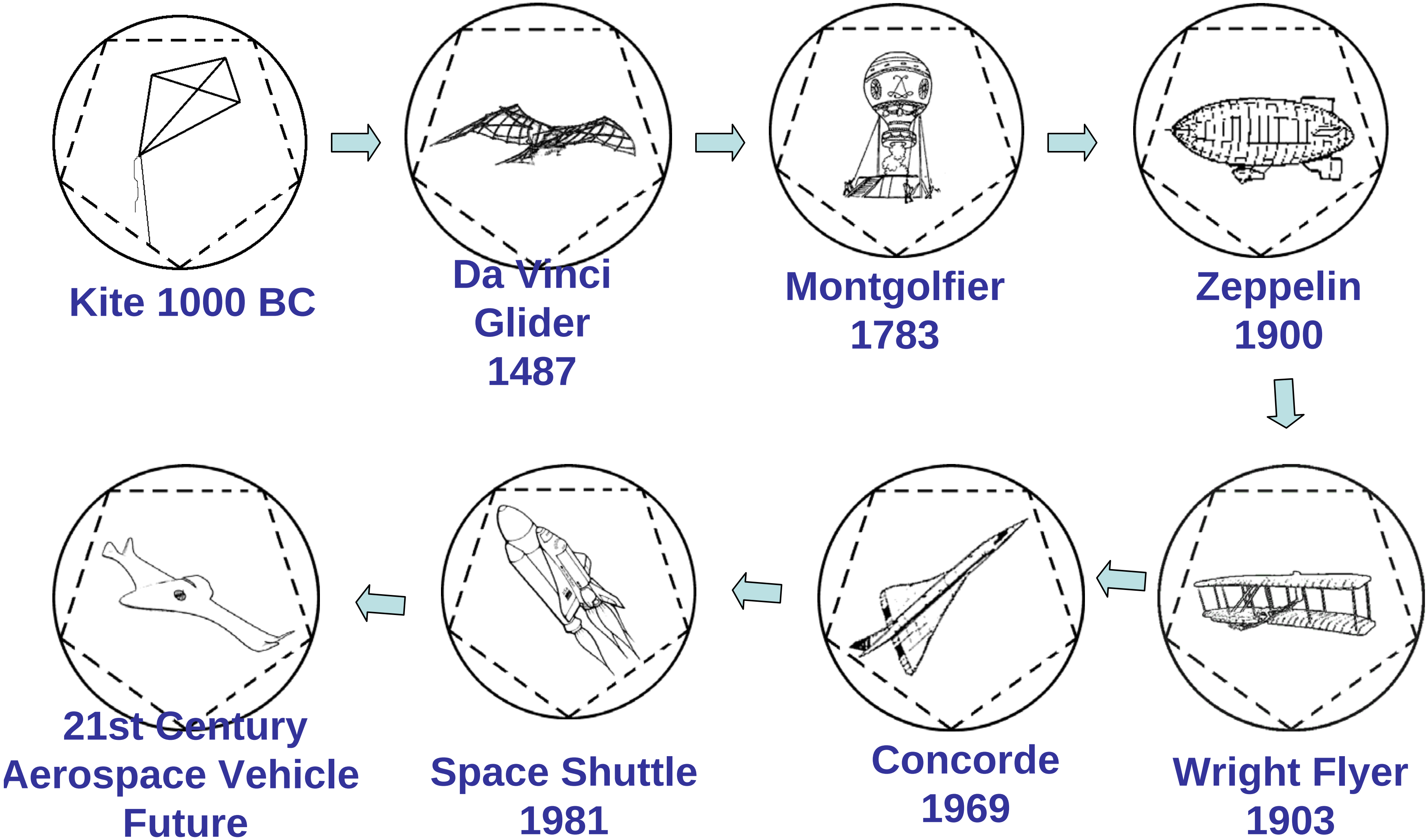
RET Teachers: Amy Jameson, Melissa Burns

SUMMER RET Program, 2010

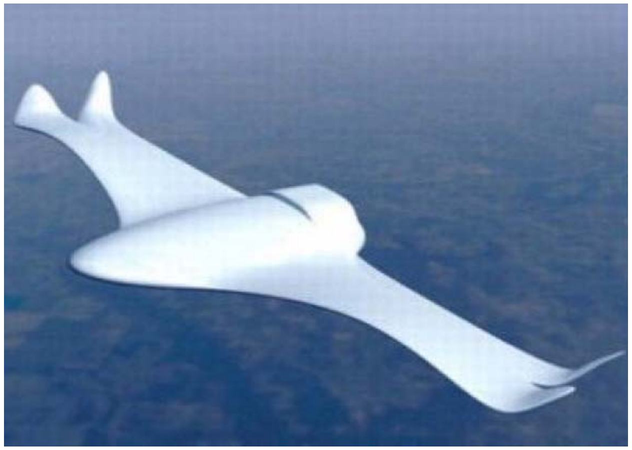
Flight - Major Milestones



http://www.nasaexplore.com/extras/cof/cof.ht

Aircraft of the Future

- Aircraft of the future will:
  - employ fully integrated, embedded **"smart" materials and actuators**
  - enable aircraft **wings with unprecedented levels of aerodynamic efficiencies and aircraft control**.



- **NASA** is aggressively promoting research on bio-inspired flight.
- We anticipate rapidly changing the way we think about air transportation:
  - incorporation of these new technologies
  - research methods,
  - human **creative and exploratory spirit**

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Background: Definition of Strouhal Number in Birds

$$St = \frac{fA}{u}$$

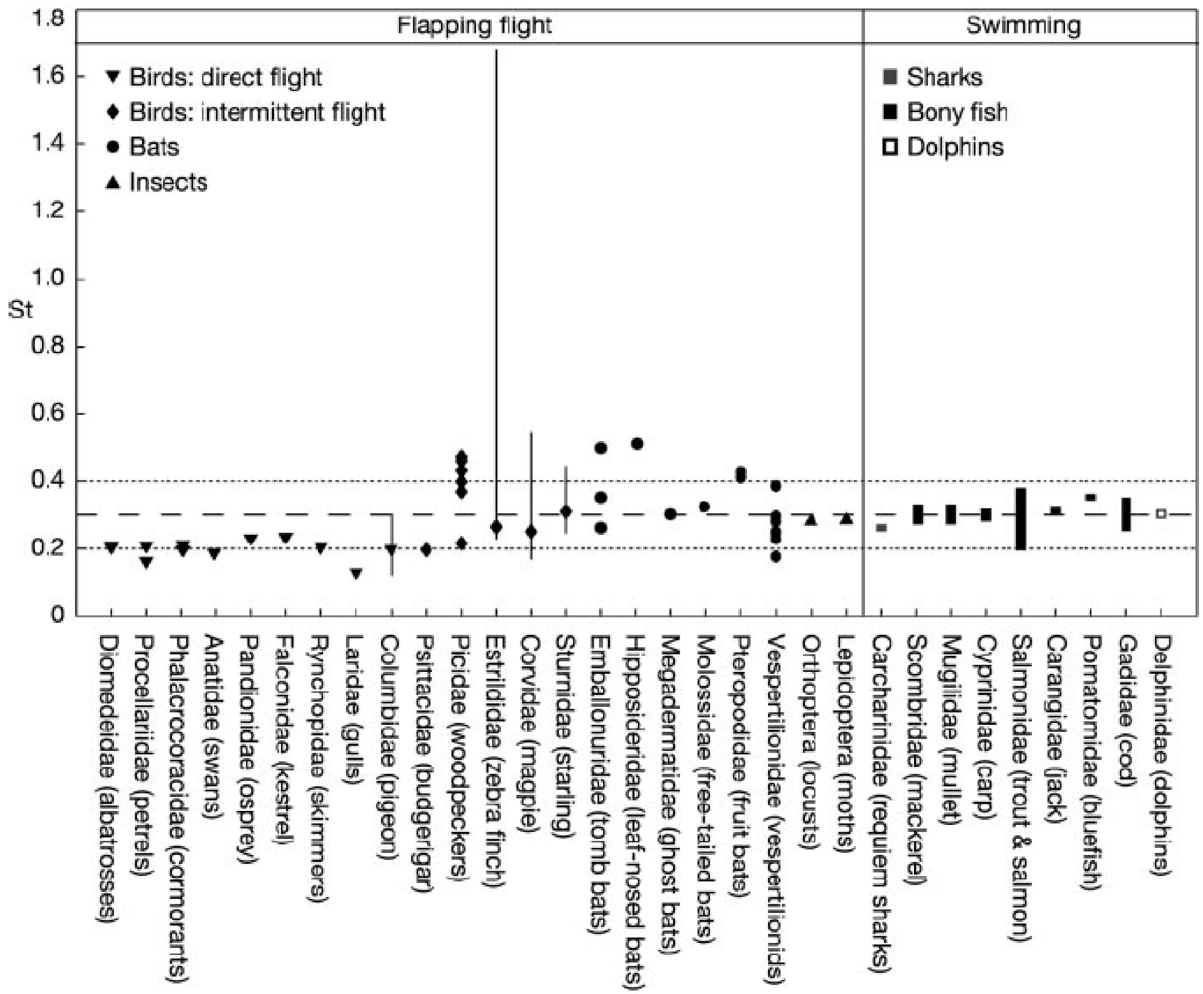
f =stroke frequency

A =Amplitude (wing tip) *or Cylinder Diameter, D*

u = Forward Speed

The Strouhal Number is known to govern a well-defined series of vortex growth and shedding regimes for airfoils undergoing pitching and heaving motions.

Background: Taylor et al.'s chart of Strouhal numbers for flapping flight and swimming



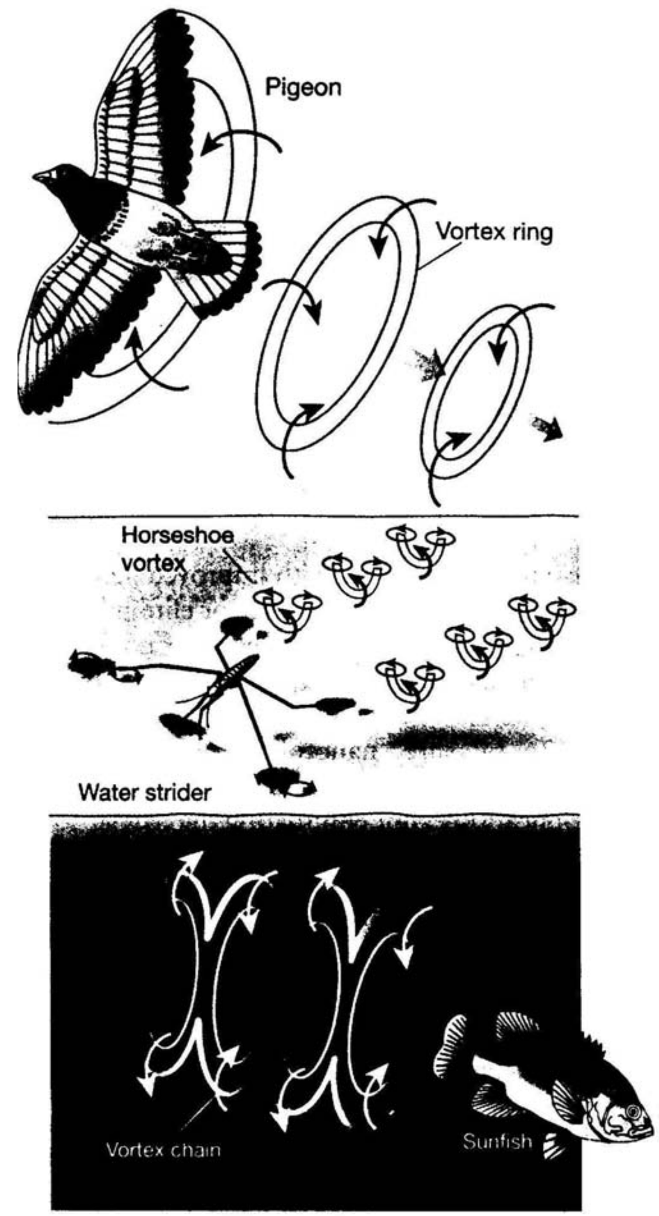
Ref: Taylor , Nudds and Thomas

NATURE | VOL 425 | 16 OCTOBER 2003 | www.nature.com/nature

Background: Propulsive Efficiency

- Natural Selection favors high propulsive efficiency in dolphins, sharks, and boned fish
- Birds also achieve this during cruise
- This propulsive efficiency peaks within St of

  $0.2 < St < 0.4$
- An isolated flapping airfoil has a propulsive efficiency that peaks at St=.3



Ref: Dickinson, Nature, Vol. 24, August 2003

Typical Wing Loading Values

•**This graph shows the proportional relationship between weight and wing loading for various species of birds and types of aircraft.**

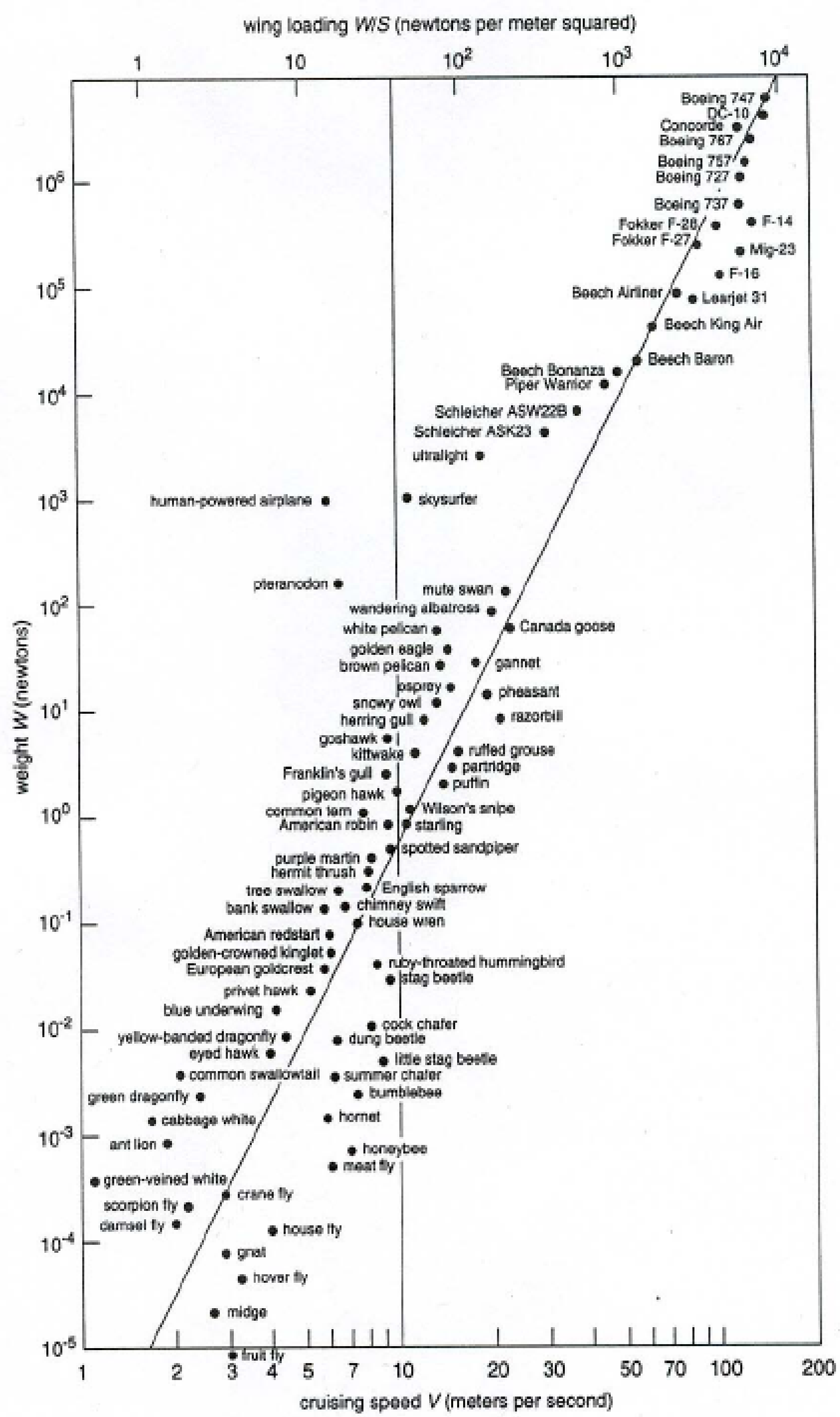
•**The vertical line marks a cruising speed of 10 meters/second (22mph) and the diagonal line is a reference "trend line".**

•**Birds and aircraft that lie on or very close to this line fit the standard form, with ordinary wings and middle-of-the-road wing loading.**

• **Flyers that lie off the line usually have special design requirements. Notice that the graph includes insects (the house fly), birds (e.g. the sparrow) and airplanes (e.g. Boeing 737).**

•**All follow the same physics of flight!!!**

•***Image taken from Tennekes, Henk. The Simple Science of Flight. Cambridge, MA: MIT Press, 1997***



The Cost of Flight

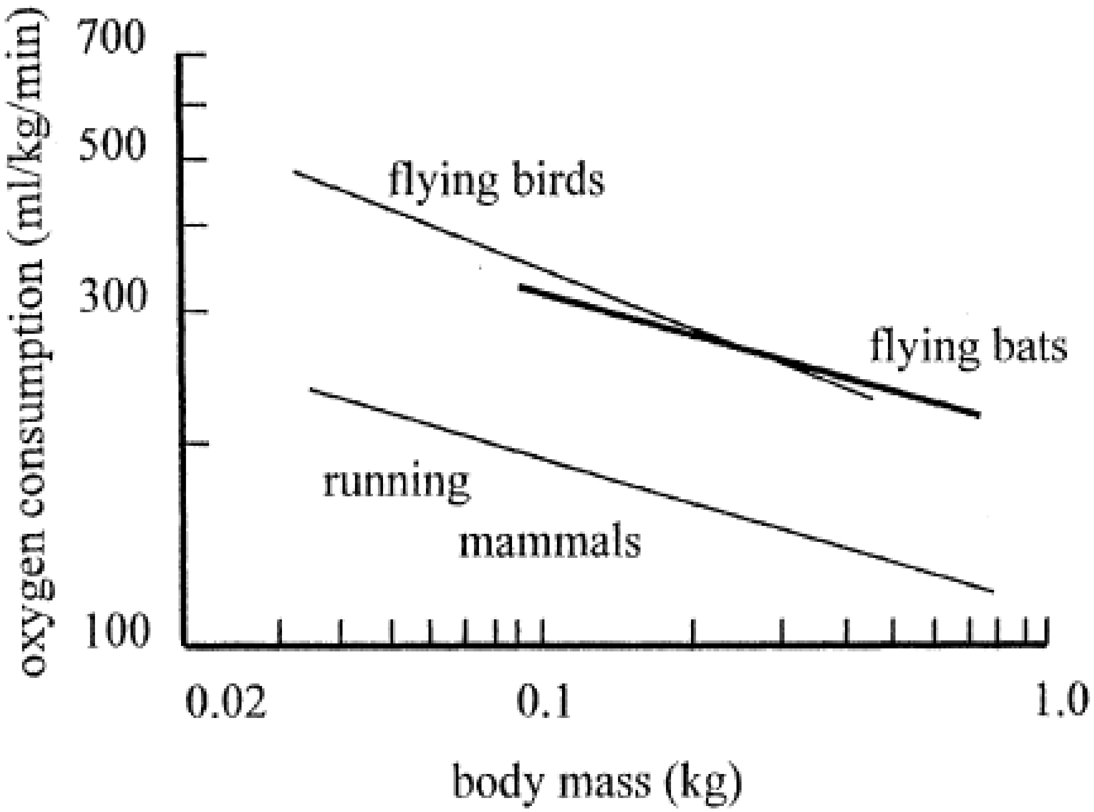


Fig. 2.9. The cost of locomotion in relation to body size. As animals get bigger, the amount of energy consumed per kg of body weight (in this case oxygen consumption) declines—locomotion becomes more efficient. Flight in both birds and bats is about twice as expensive as running in mammals (adapted from Thomas, 1987).

Morphing in Nature

- **Bats have *very efficient* wings, and they have a unique ability to morph wing camber.**
- **Morphing (changing camber and aspect ratio) makes bats far more maneuverable than birds especially at very low speeds.**
- **Bats’ wings consist of long, thin, lightweight bones, held together by a skin membrane, which enables the rapid change in wing camber.**

Sequence of Bat Flight

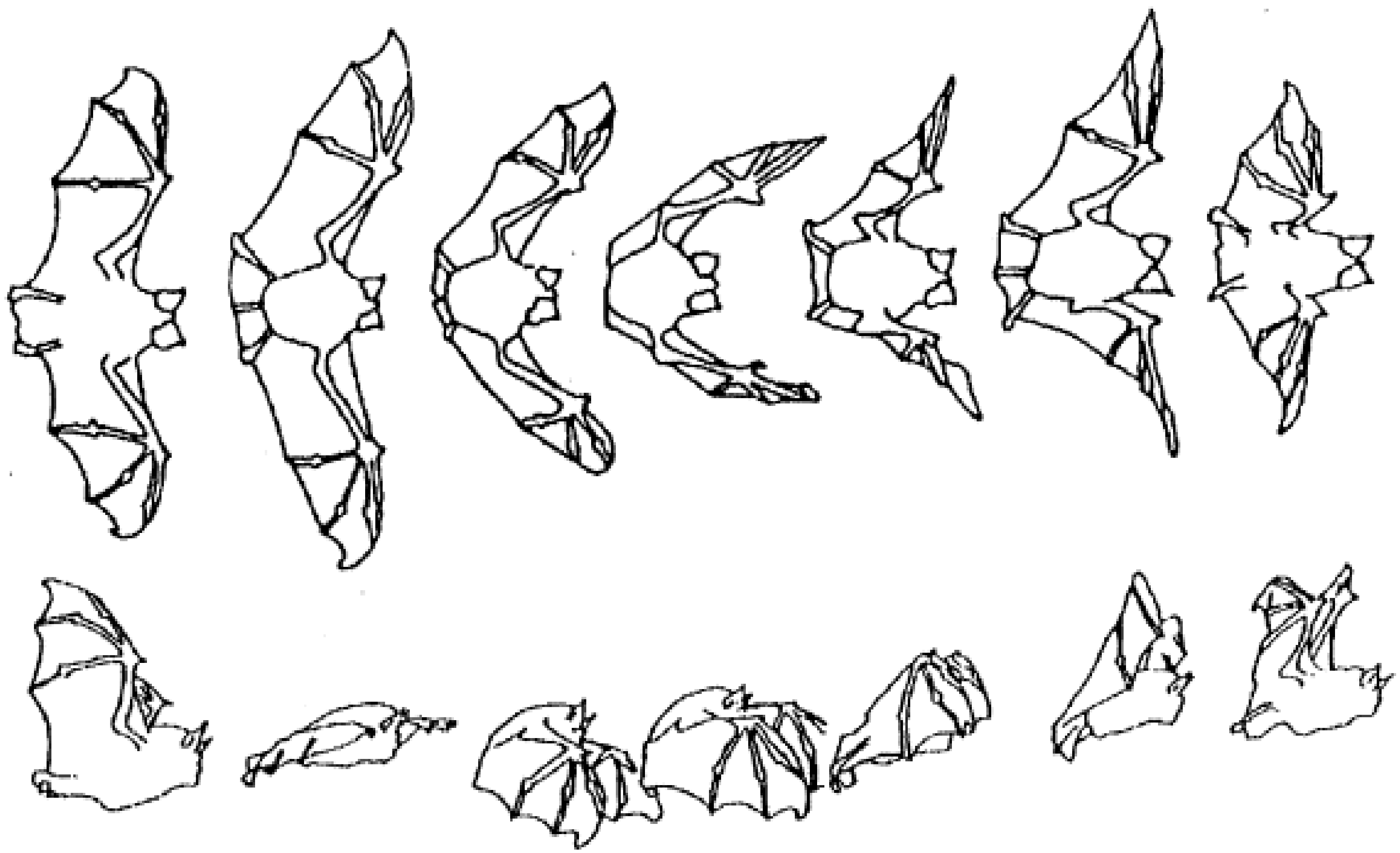


Fig. 2.6. Wing movements during slow flight of a greater horseshoe bat (from Aldridge, 1986).

Summary and Project Goals

- The proposed study will:
  - review the basic principles of flight
  - investigate the trends in airfoil design as we move towards bio-inspired flight.
  - Provide teachers with required material to prepare exciting classrooms lessons on this topic

Summary and Project Goals

- Three Phase program:
  - The **first phase** is obtaining an appreciation for the underlying physics concerning principles of flight. Theoretical studies will be complimented with wind-tunnel model testing.
  - In the **second phase** the RET team will work on the ZAGI hand held glider kit. The gliders will be flight tested.
  - In the **third phase**, the team will use the in-house morphing design software, AEROMORPH to develop and predict the performance of new and unique bio-inspired airfoil designs.