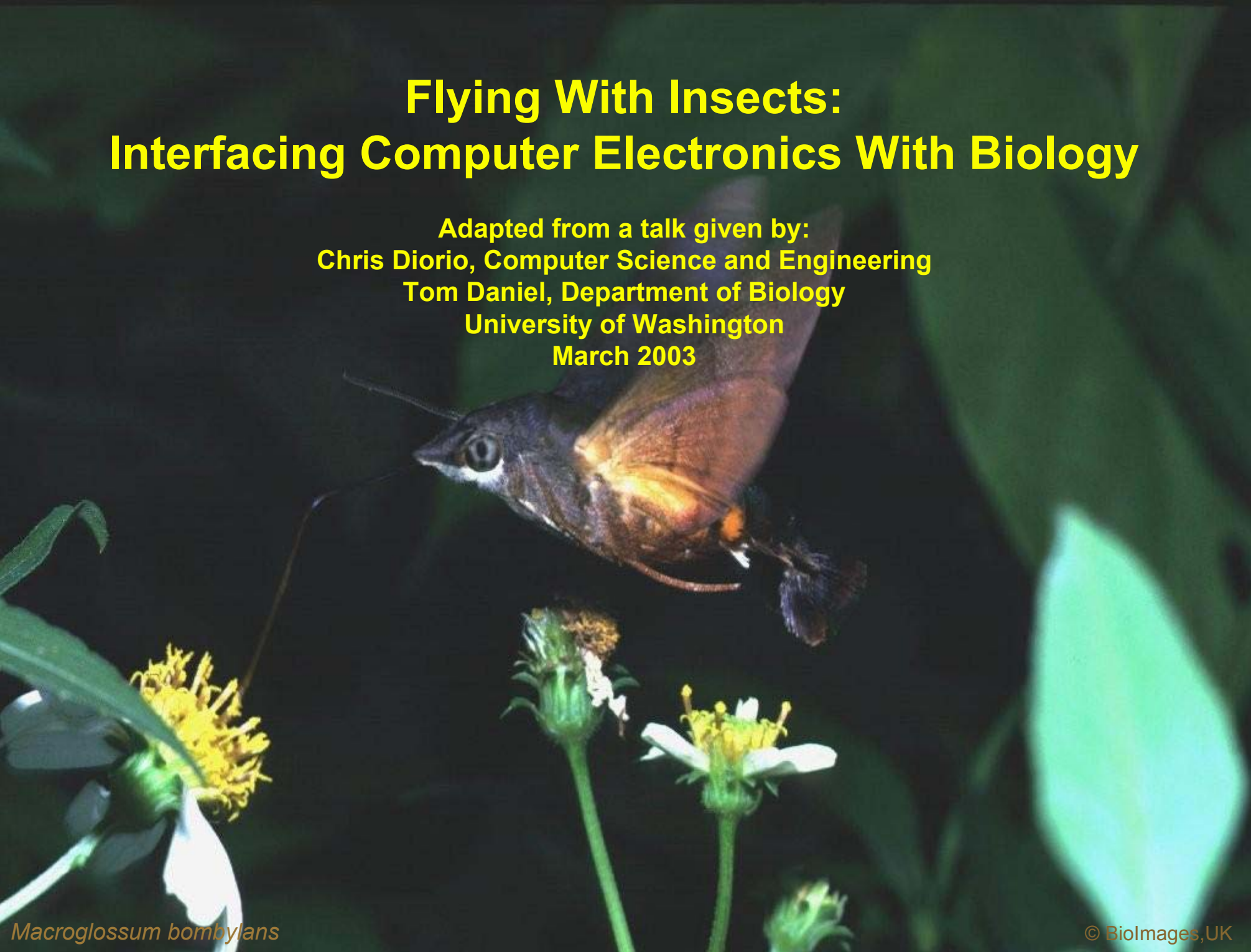
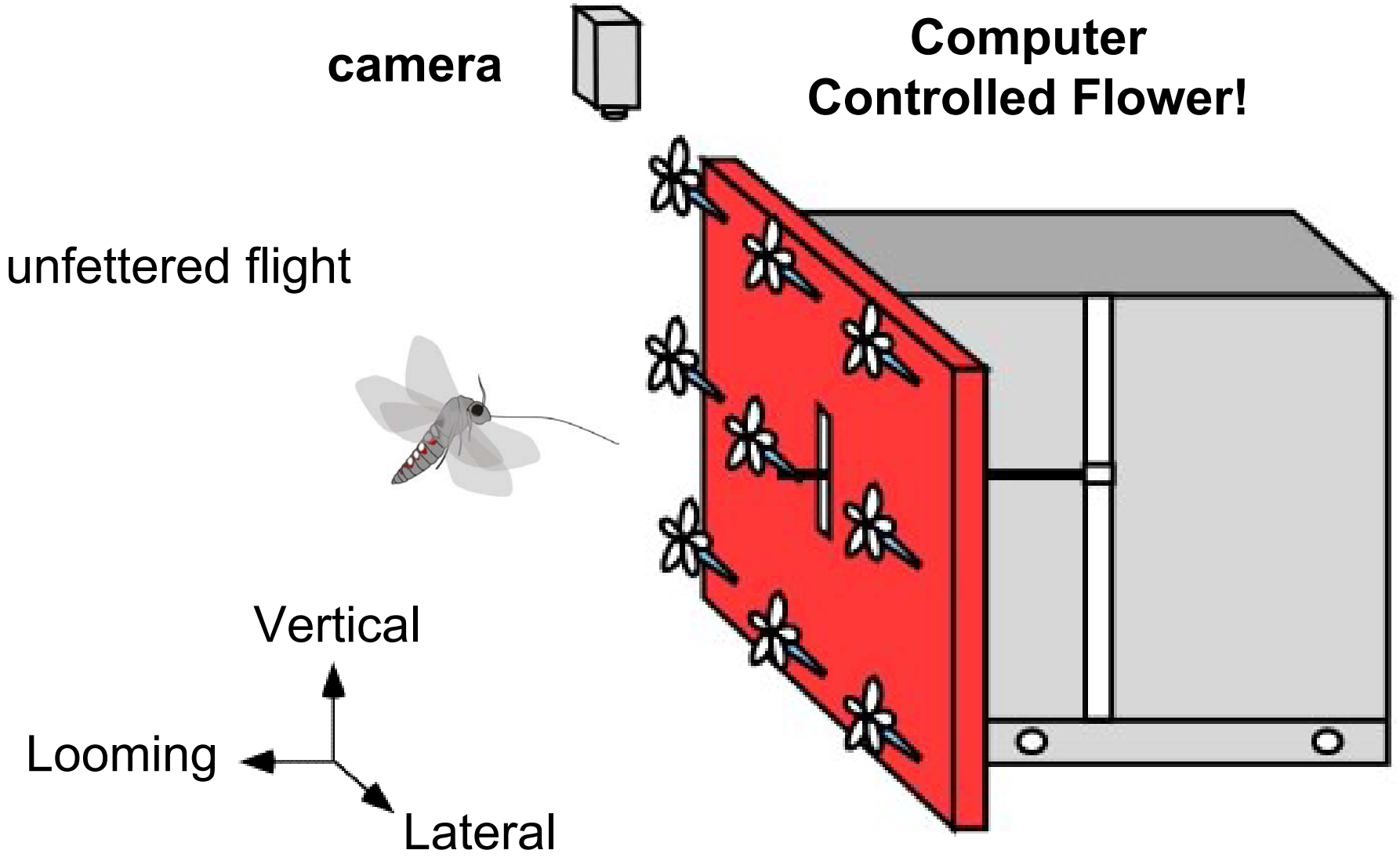
Flying With Insects:
Interfacing Computer Electronics With Biology

Adapted from a talk given by:
Chris Diorio, Computer Science and Engineering
Tom Daniel, Department of Biology
University of Washington
March 2003



Macroglossum bombylans

“Robo-Bush”

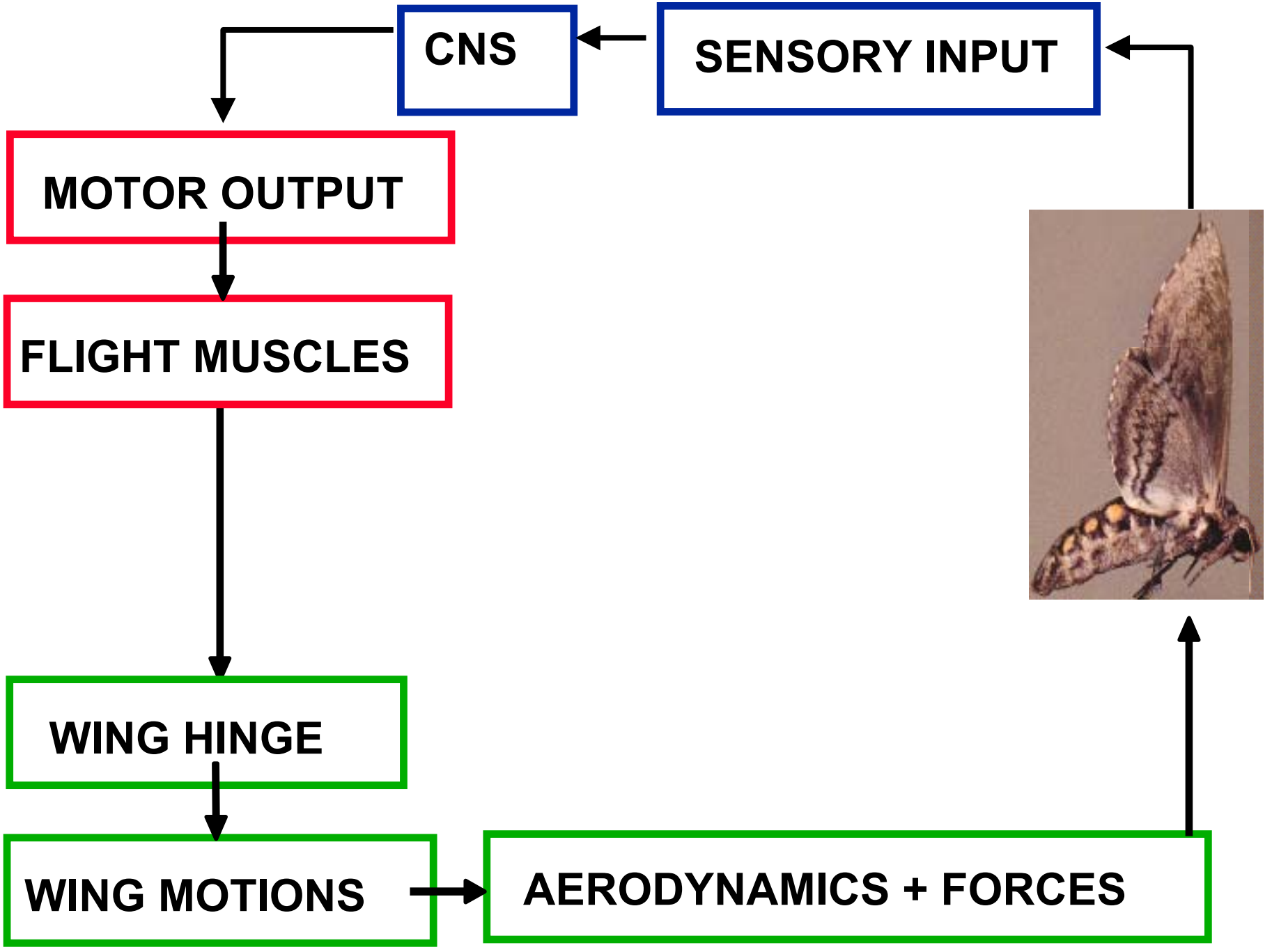


Carlos Moreno

Looming/Vertical

← Looming

Vertical →

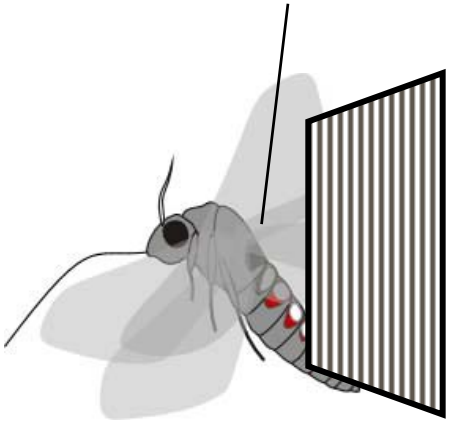

CNS
SENSORY INPUT
MOTOR OUTPUT
FLIGHT MUSCLES
WING HINGE
WING MOTIONS
AERODYNAMICS + FORCES

CNS

SENSORY INPUT

MOTOR OUTPUT

FLIGHT MUSCLES

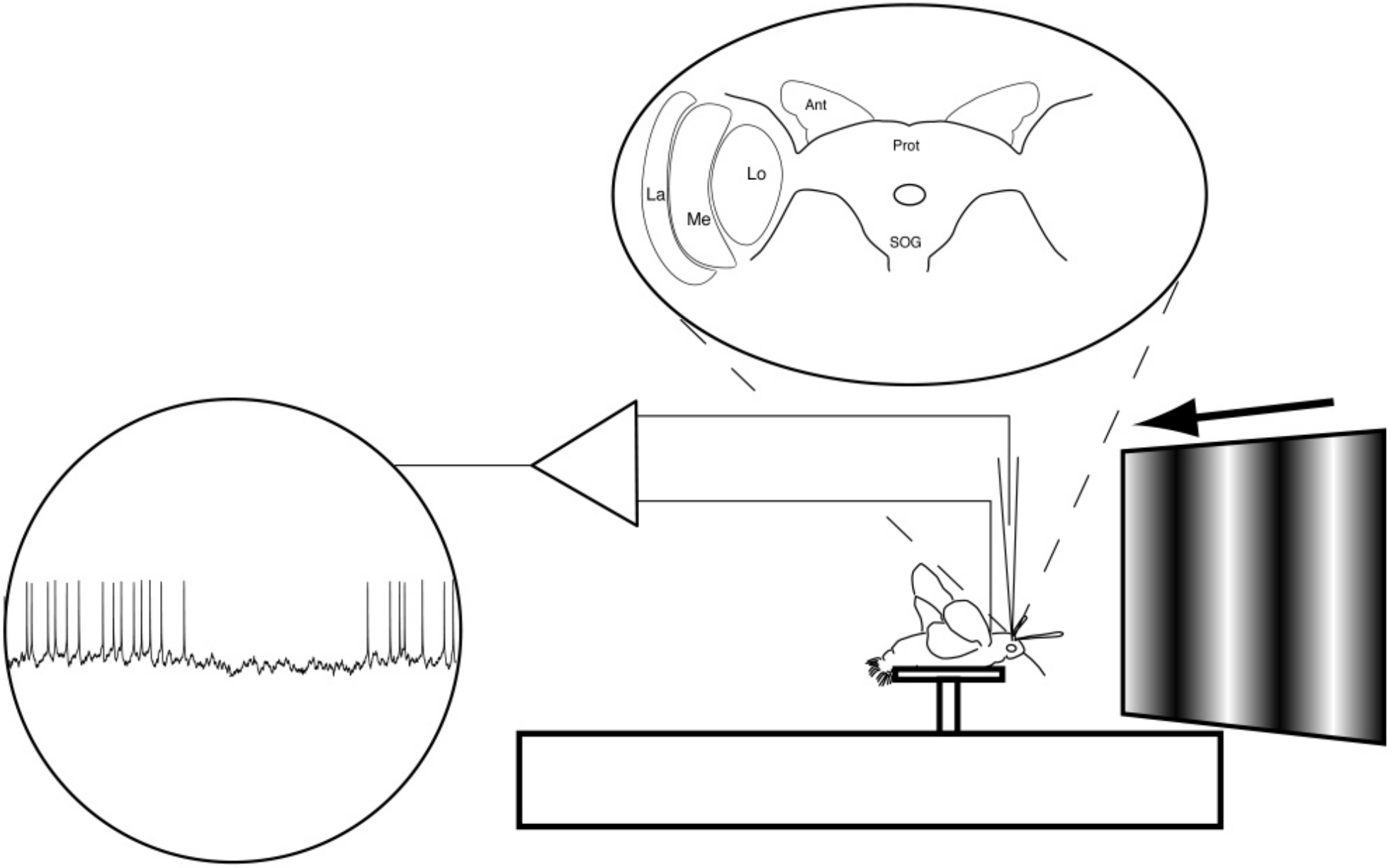


WING HINGE

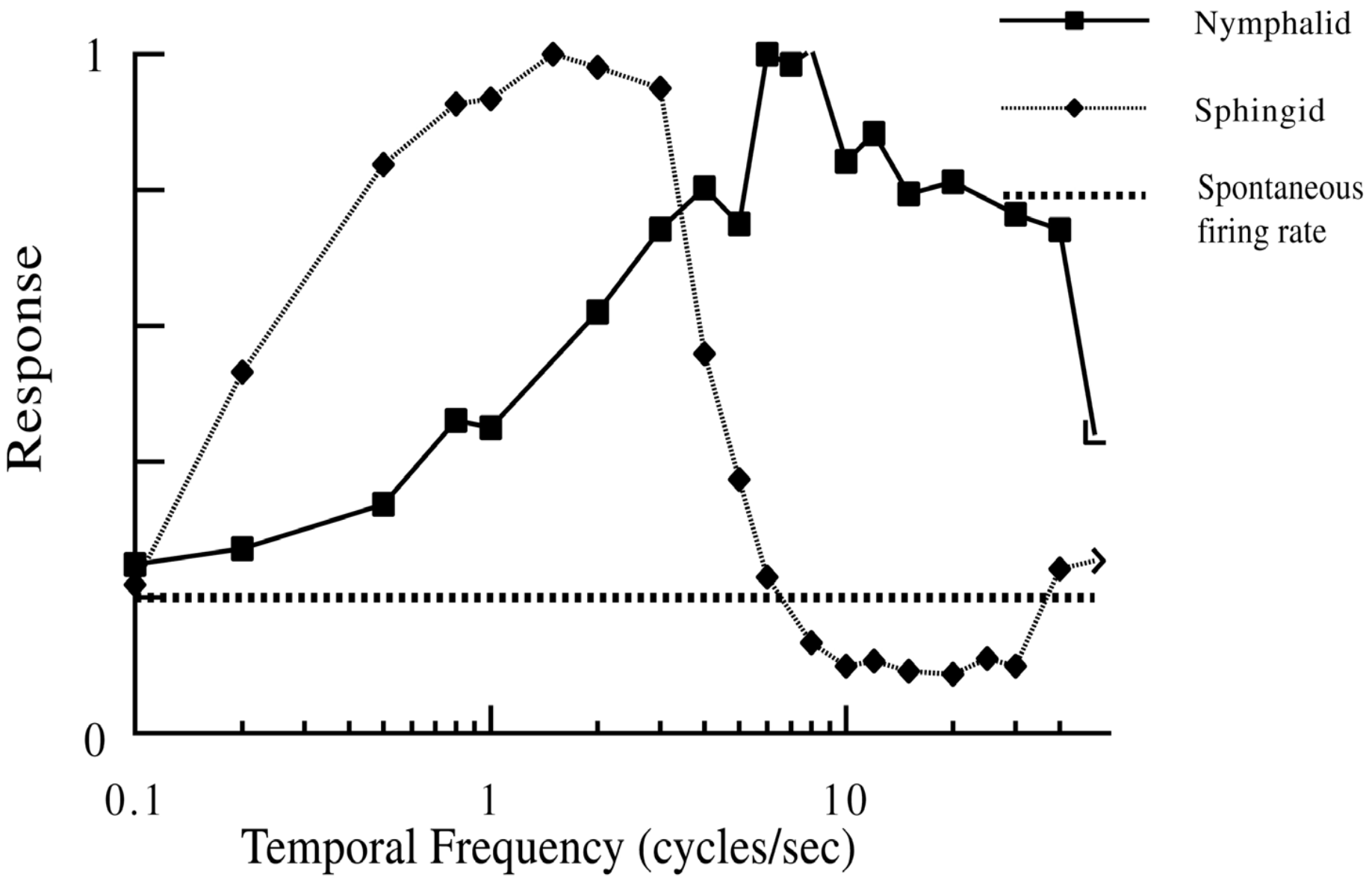
WING MOTIONS

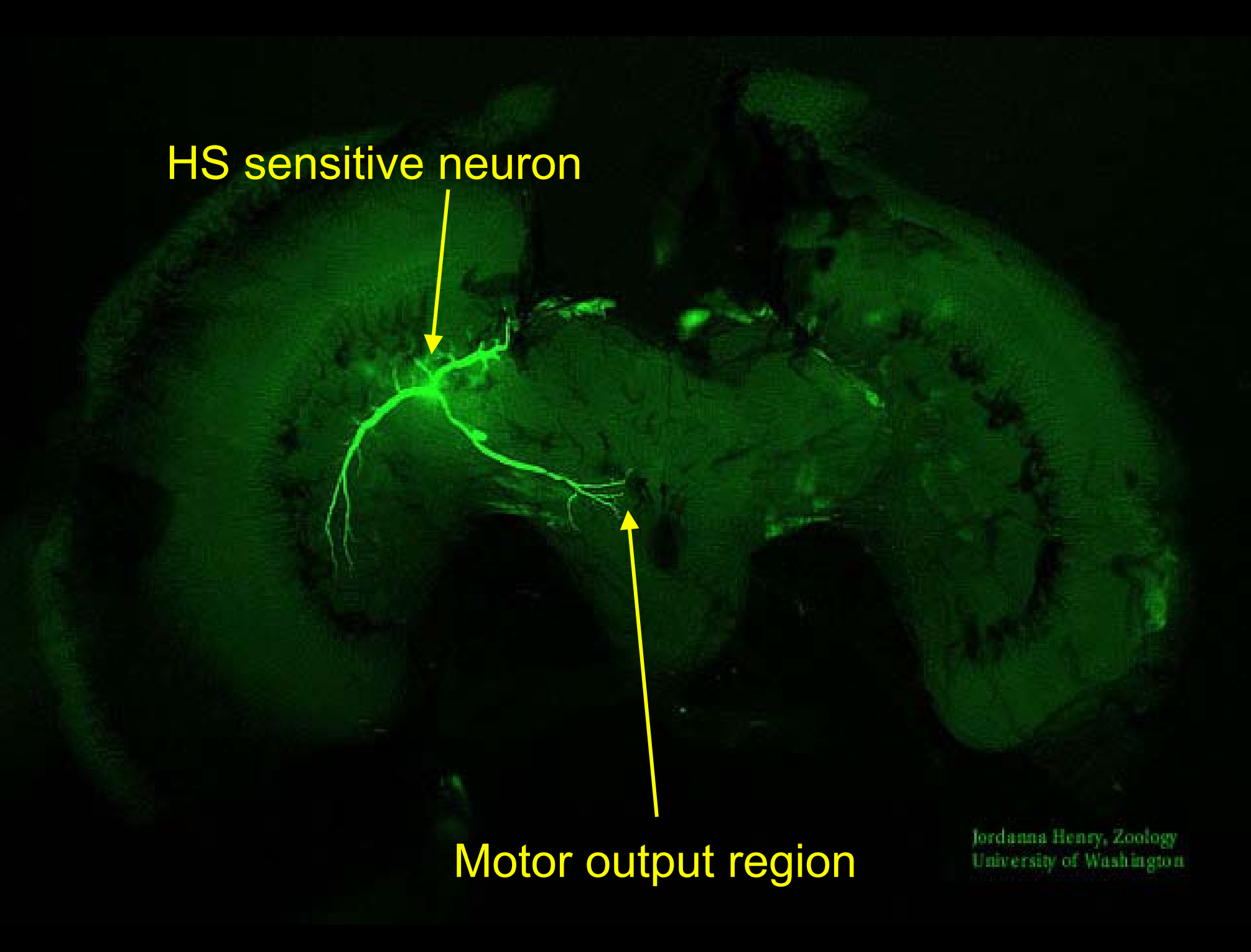
AERODYNAMICS + FORCES

Experimental method



Temporal filtering (with aliasing?)




HS sensitive neuron
Motor output region
Jordanna Henry, Zoology
University of Washington

Jordanna Sprayberry,
Mark Willis

CNS

SENSORY INPUT

MOTOR OUTPUT

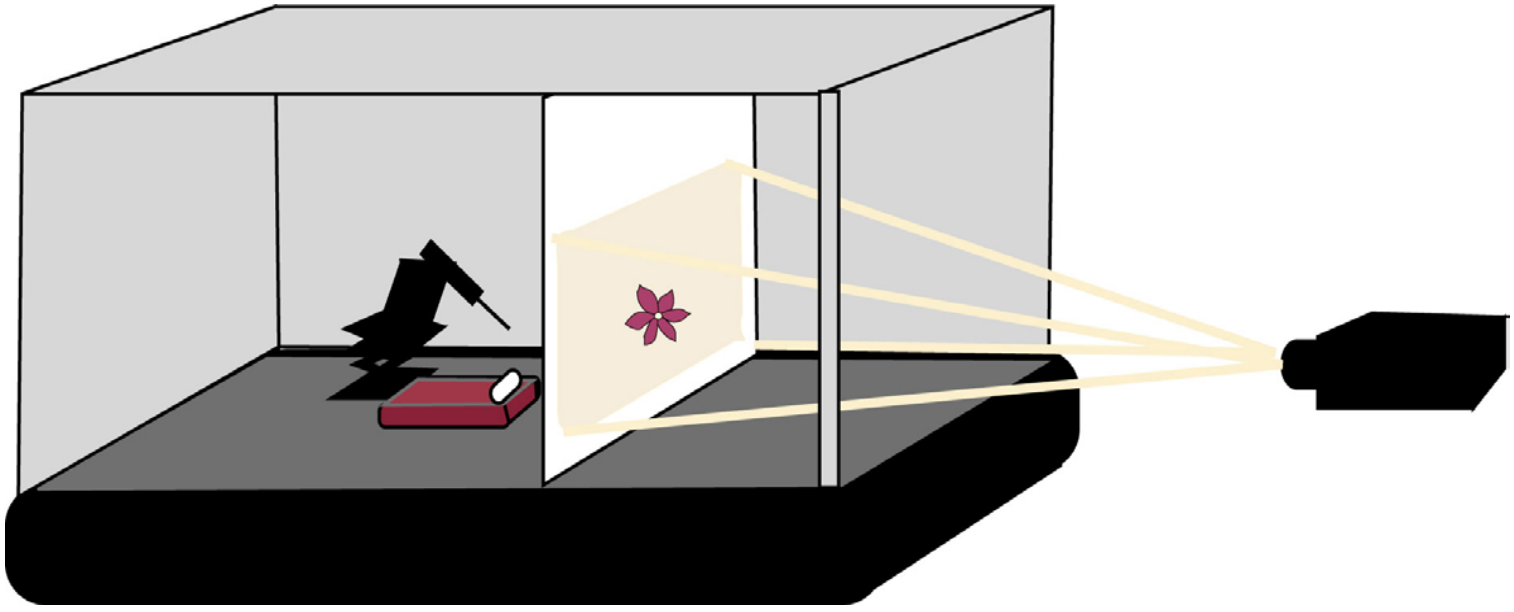
FLIGHT MUSCLES

WING HINGE

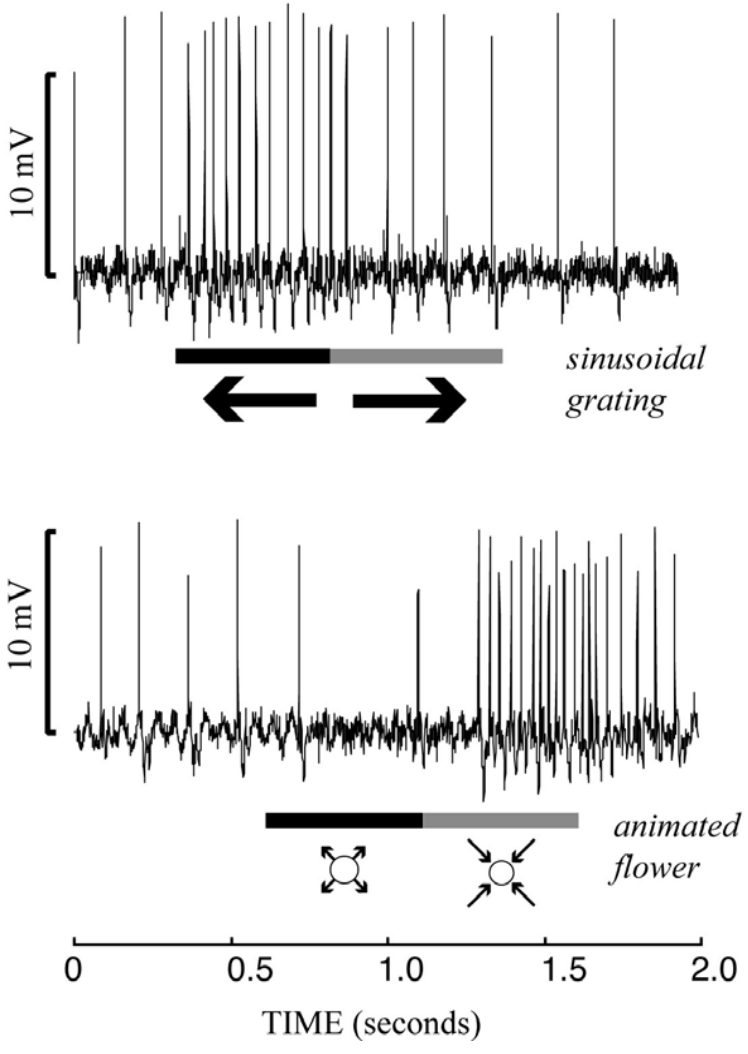
WING MOTIONS

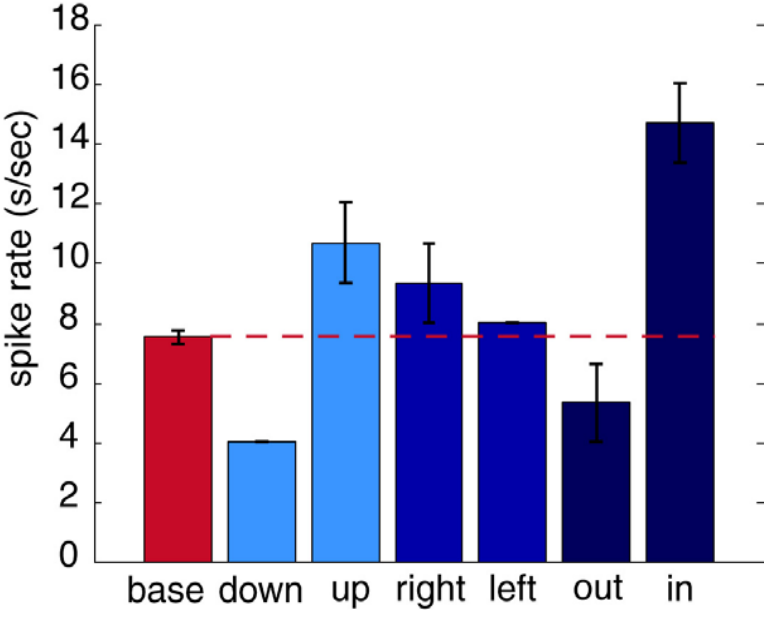
AERODYNAMICS + FORCES

Experimental Setup

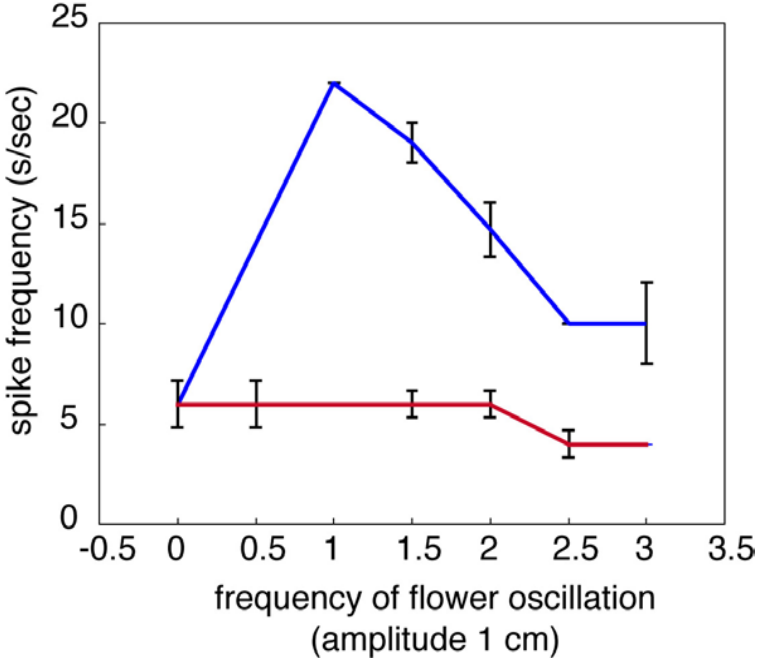


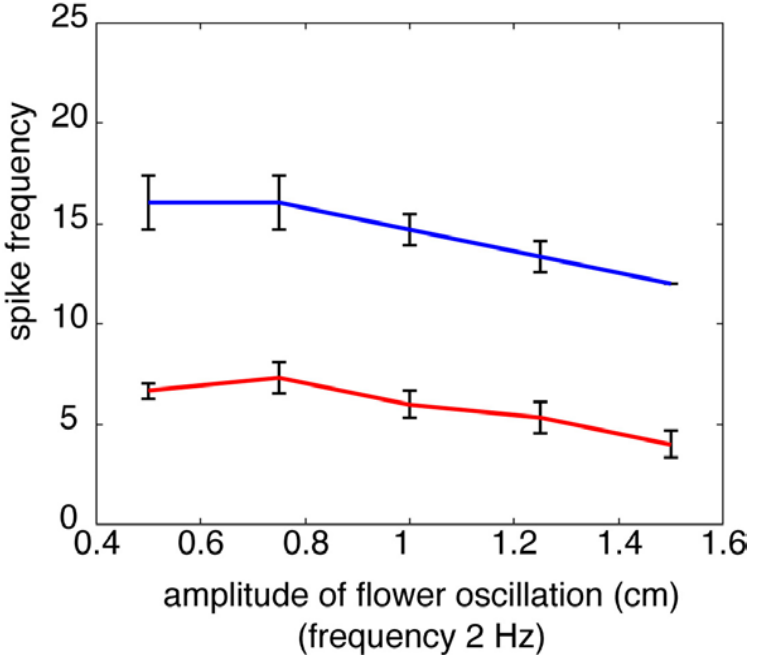
Units that respond to both wide-field and animated flower motion.



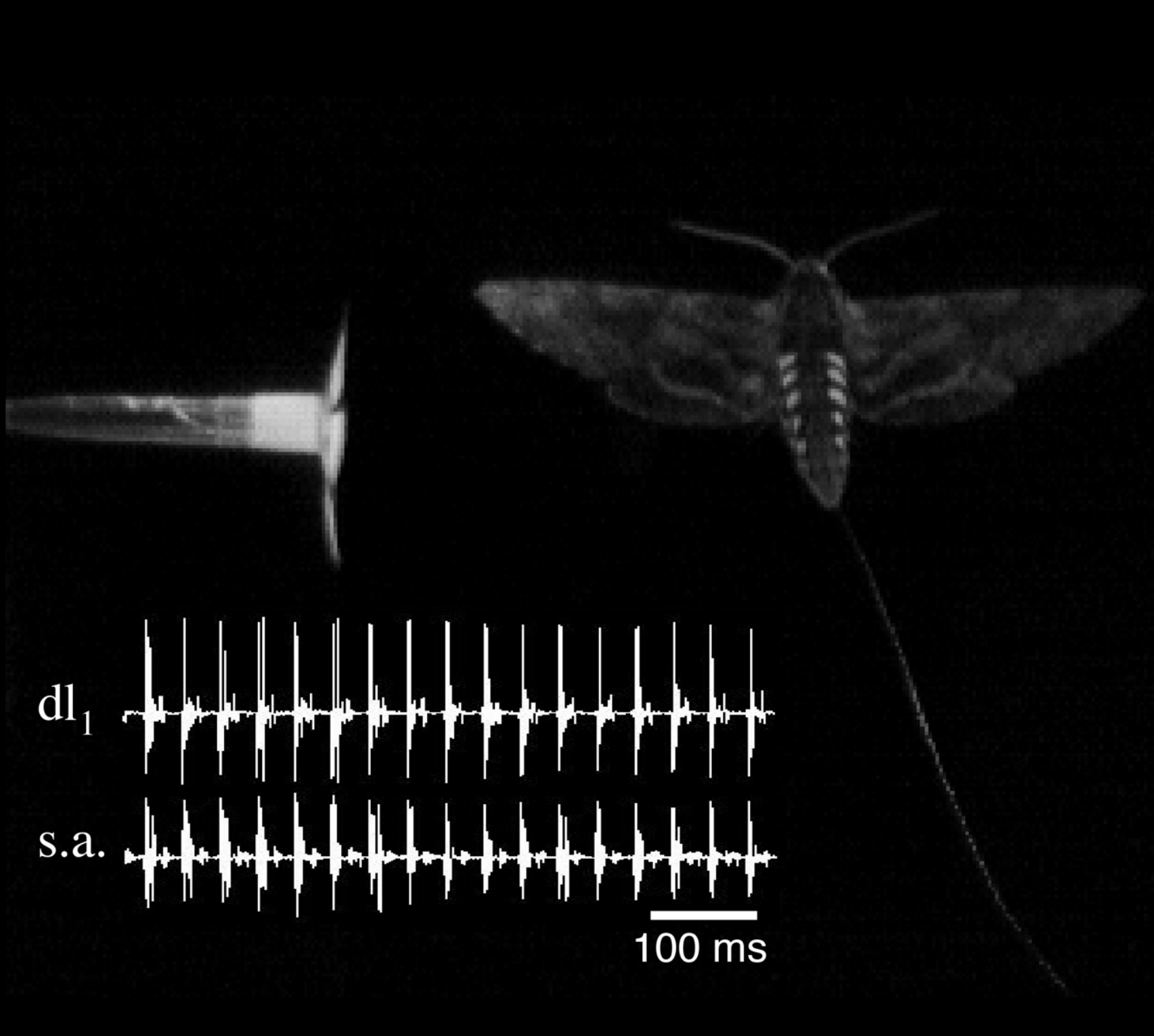


Frequency and amplitude tuning of response to flower motion



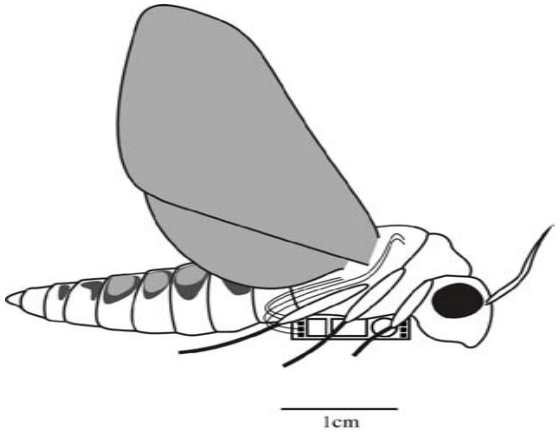


- Cell shows the same frequency optima as preliminary behavior work

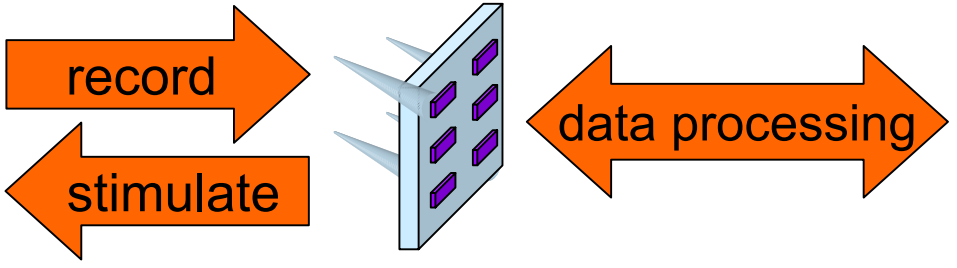

dl1
s.a.
100 ms

Implantable Microcomputer

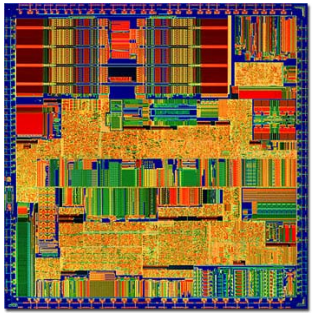
- Computer interacting with nerve tissue
  - Digitize and record from nerve tissue
  - Stimulate nerve tissue
  - Download firmware from host
  - Upload data to host



Manduca Sexta

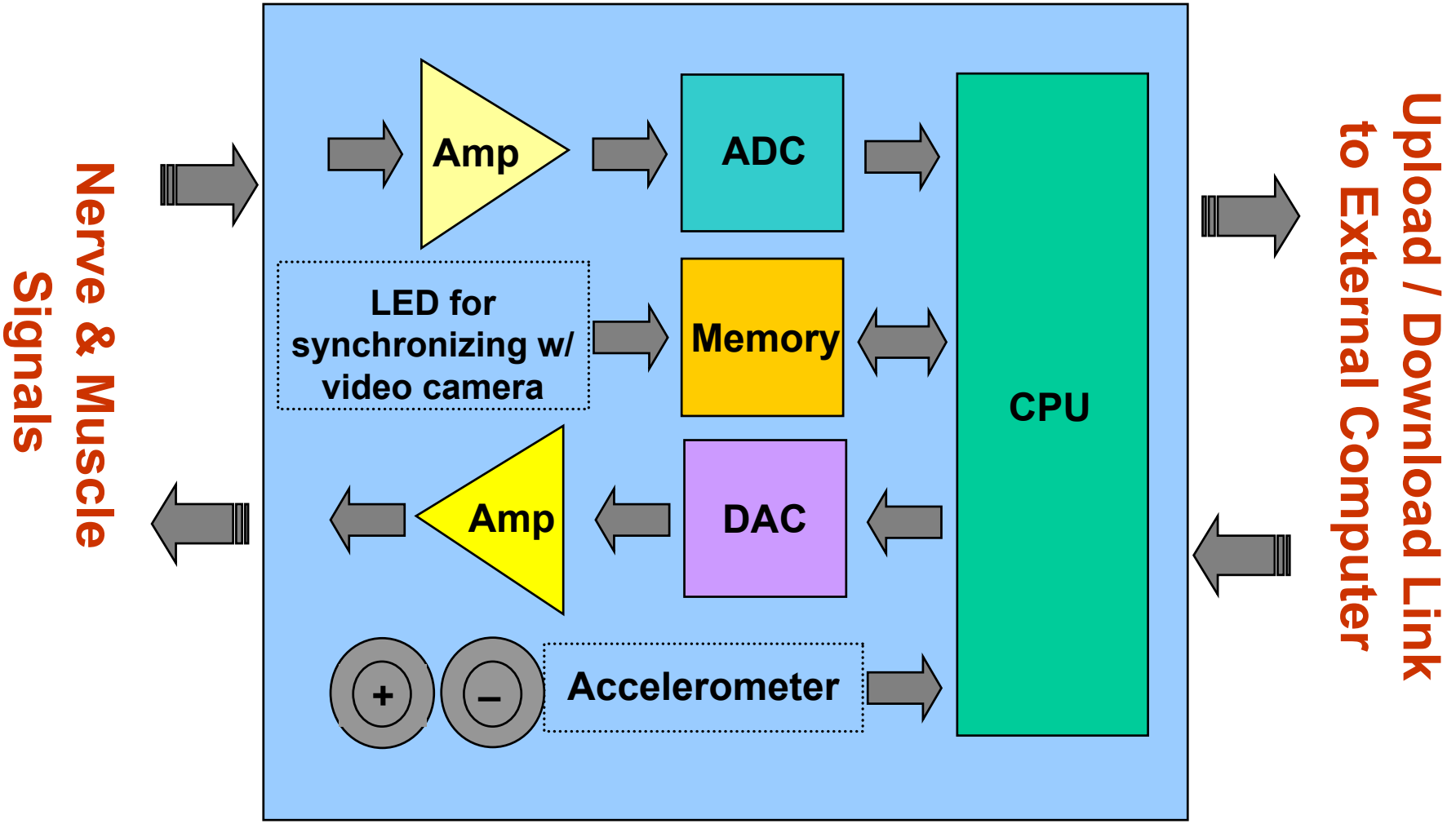


Extracellular Probe
Neural MicroProbe

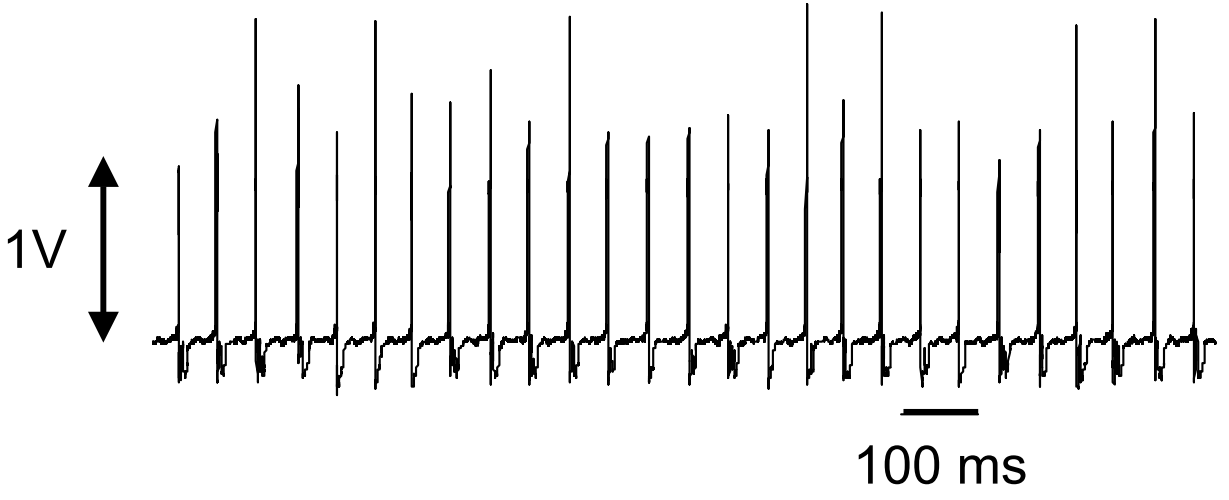


Implantable
Microcomputer

The Electronics



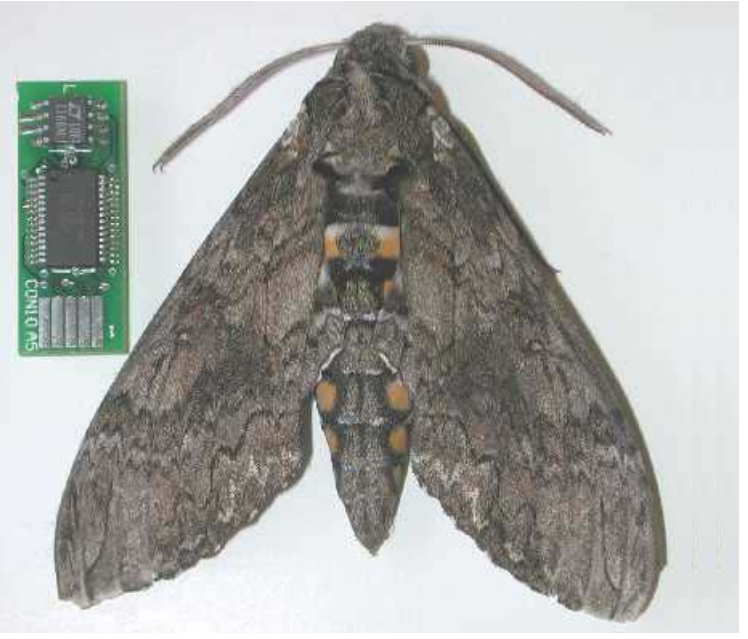
First Tethered Experiments



Tethered in-flight recording with on-board amplifiers

First NeuroPCB

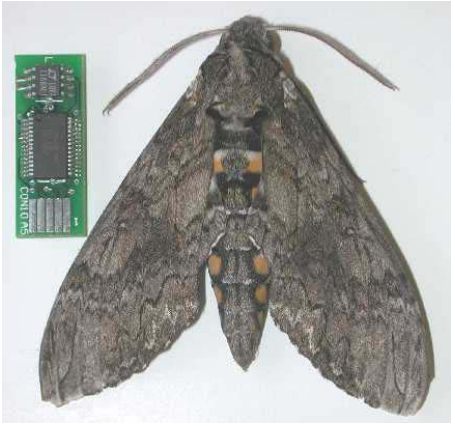
- **Inputs**
  - 2 differential channels
  - 10 ksps/channel
  - 11-bit ADC
  - Programmable gain
  - Adaptive offset correction
- **Outputs**
  - 2 direct muscle stimulation
- **Processor**
  - 8-bit, 24 MHz
- **Memory**
  - 4 Mbit serial flash
- **Power**
  - <15 mW, battery powered

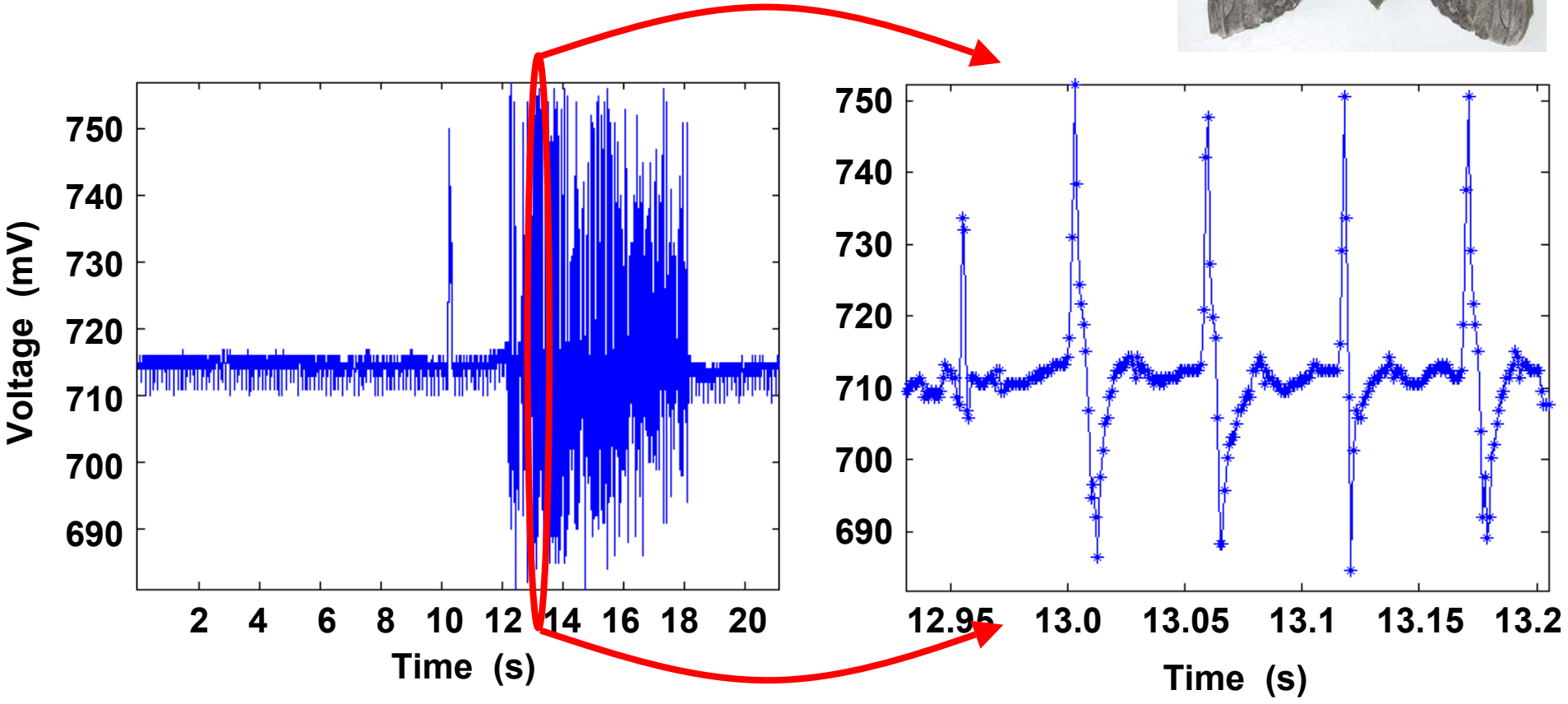


10mm x 30mm, 1.5g

NeuroPCB End-to-End Test

- Manduca DLM recordings
  - Acquire & compress data
  - Store into memory
  - Download to PC
- Issue: Moth can't fly with PCB





Revised NeuroPCB

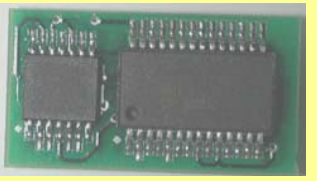
First Generation

(top)

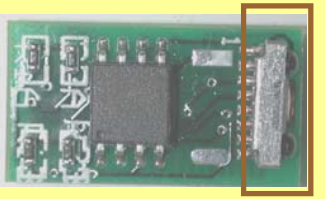
(bottom)

- Size: 1cm x 3cm x 0.5cm
- Weight: 1.47g
  (w. o. battery)

Current Generation



(top)

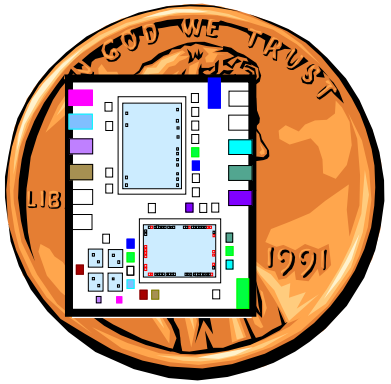


(bottom)

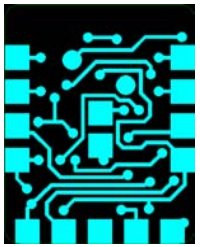
- Size: 1cm x 1.9cm x 0.4cm
- Weight: 0.85g (w. o. battery)
  Moth can hover and fly with chip
- Infrared port for remote communication

Further Miniaturization

Board size

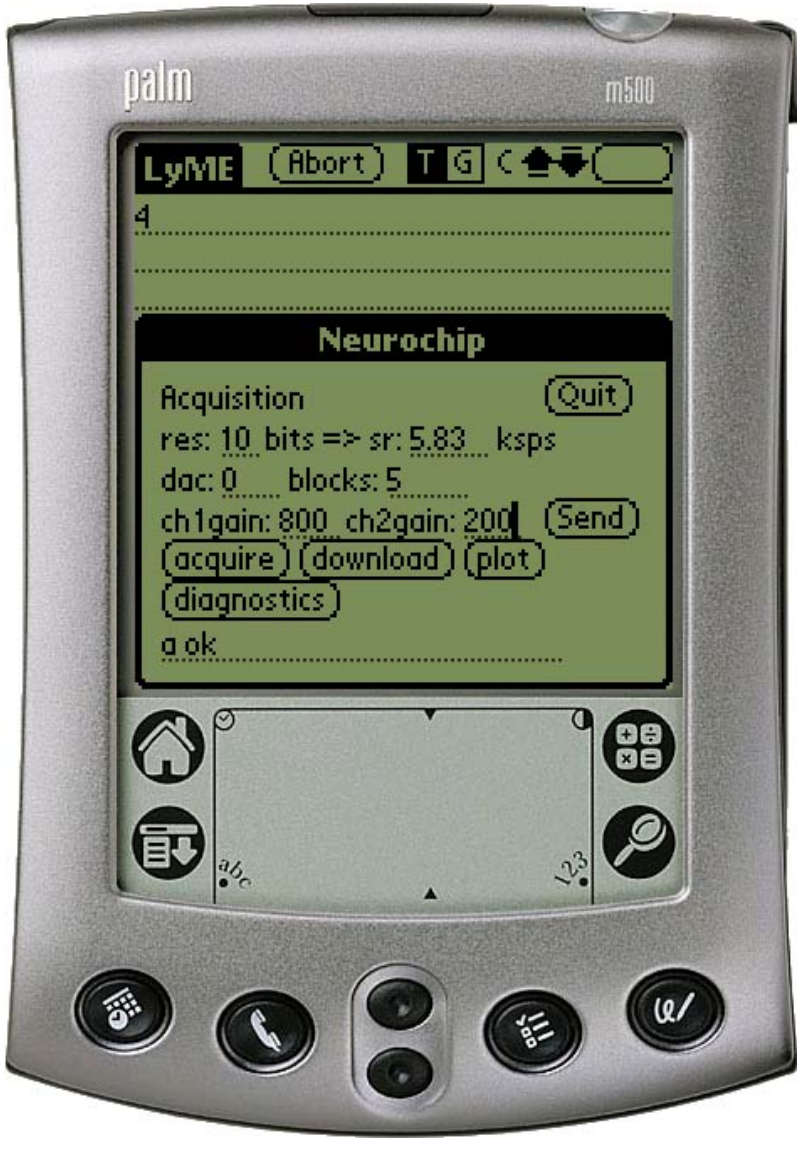


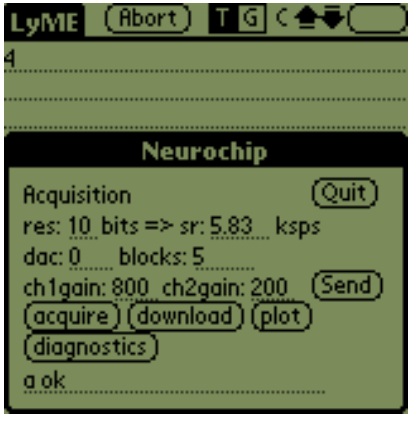
PCB Layout

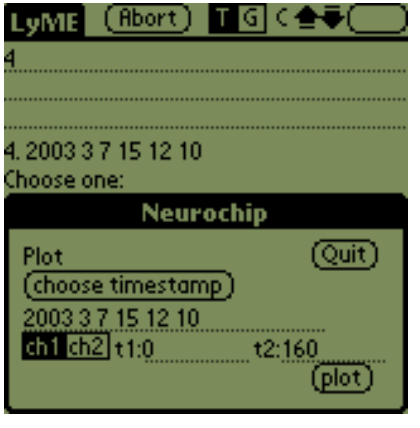


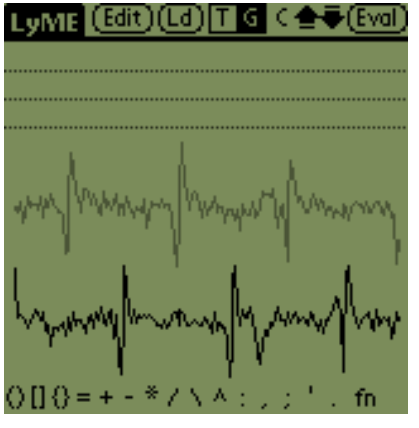
- MicroPCB
  - 1cm × 1.25cm
  - 0.25g (w. o. battery)
  - Bare dice on PCB
  - Moth will fly with chip
  - Begin testing 4-15-03

Mini-Neurolab









Data Acquisition

Data Download

Data Analysis

Software platform: LyME, a Matlab-compatible app running on PalmOS.

CNS

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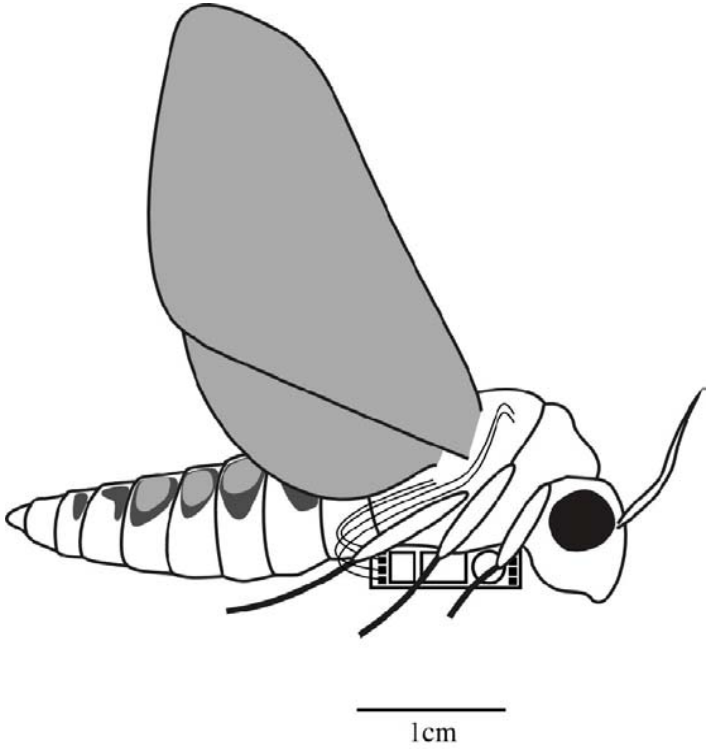
MOTOR OUTPUT

FLIGHT MUSCLES

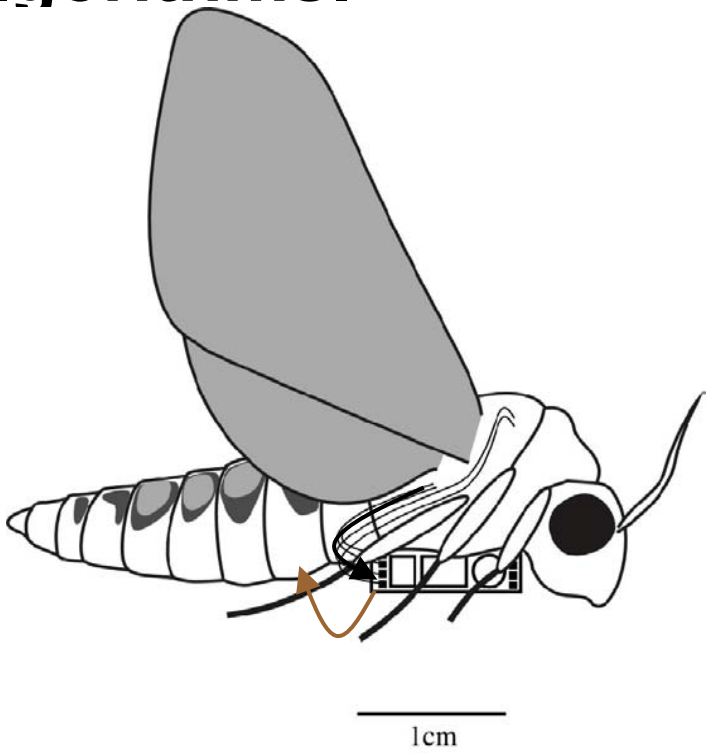


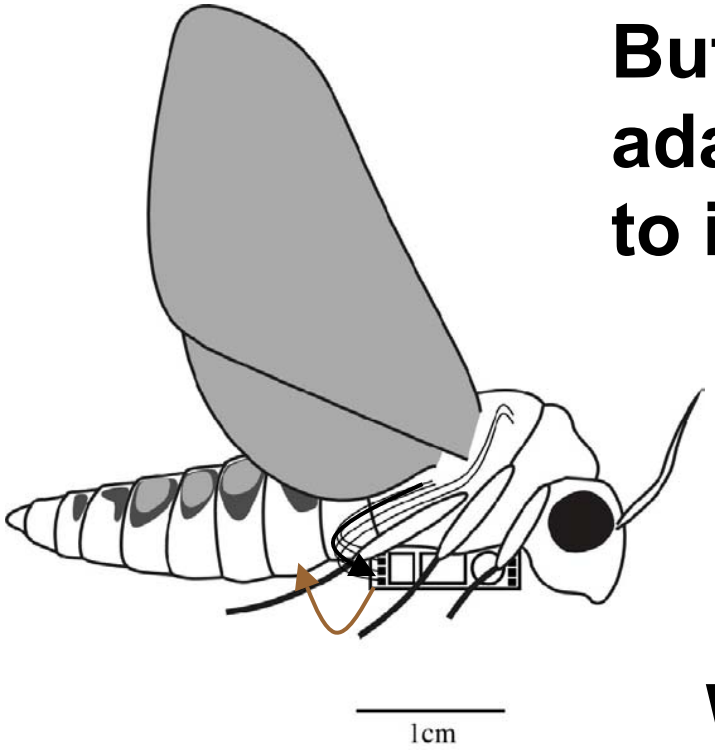
WING HINGE

WING MOTIONS

AERODYNAMICS + FORCES

A *very small* in-flight computer can both record and stimulate. If it is fully programmable, then we could implement some feedback control and some learning algorithms.





But nervous systems may adapt to the controls we wish to implement.

We will need algorithms that can adapt in response.