SECTION 4 : MUSCLE CONTRACTION AND MOTION IN ANIMALS

LECTURE 11 : TO SING OR TO FLY

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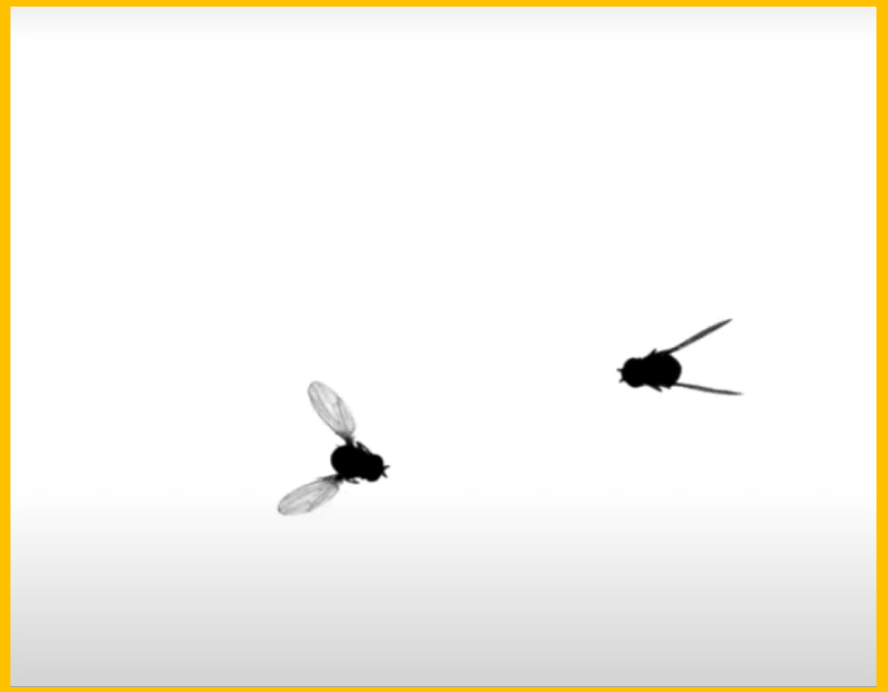
Resources :-

Multifunctional Wing Motor Control of Song and Flight

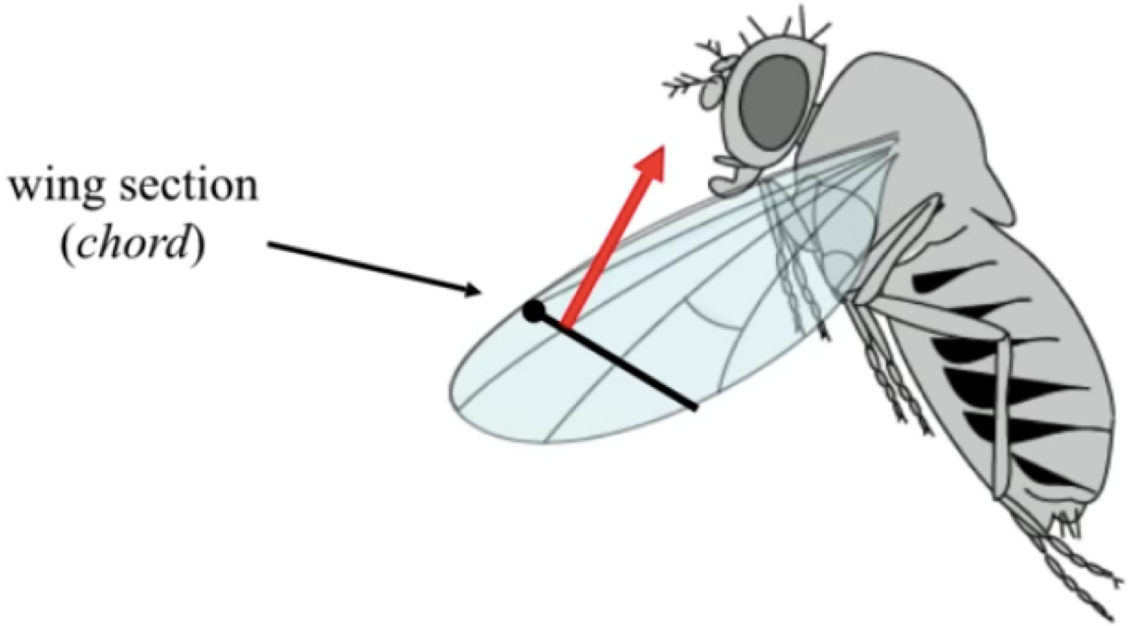
Current Biology 2018, O'Sullivan et. al.

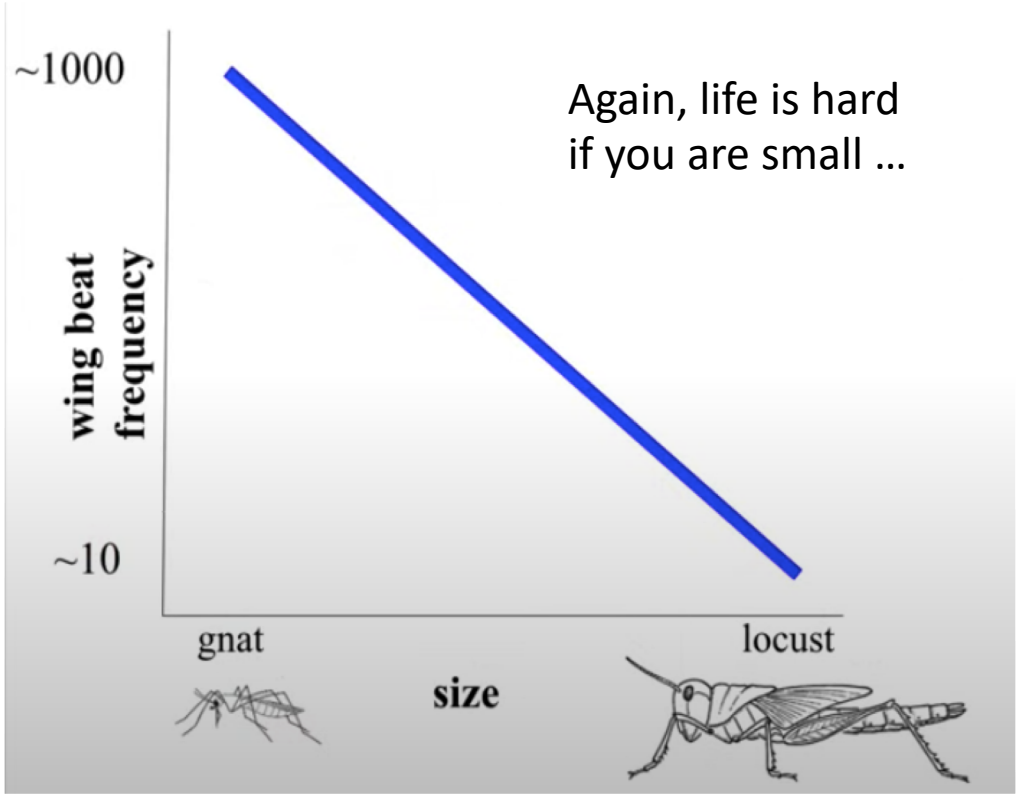
iBiology Talk -1, Michael Dickinson

iBiology Talk -2, Michael Dickinson

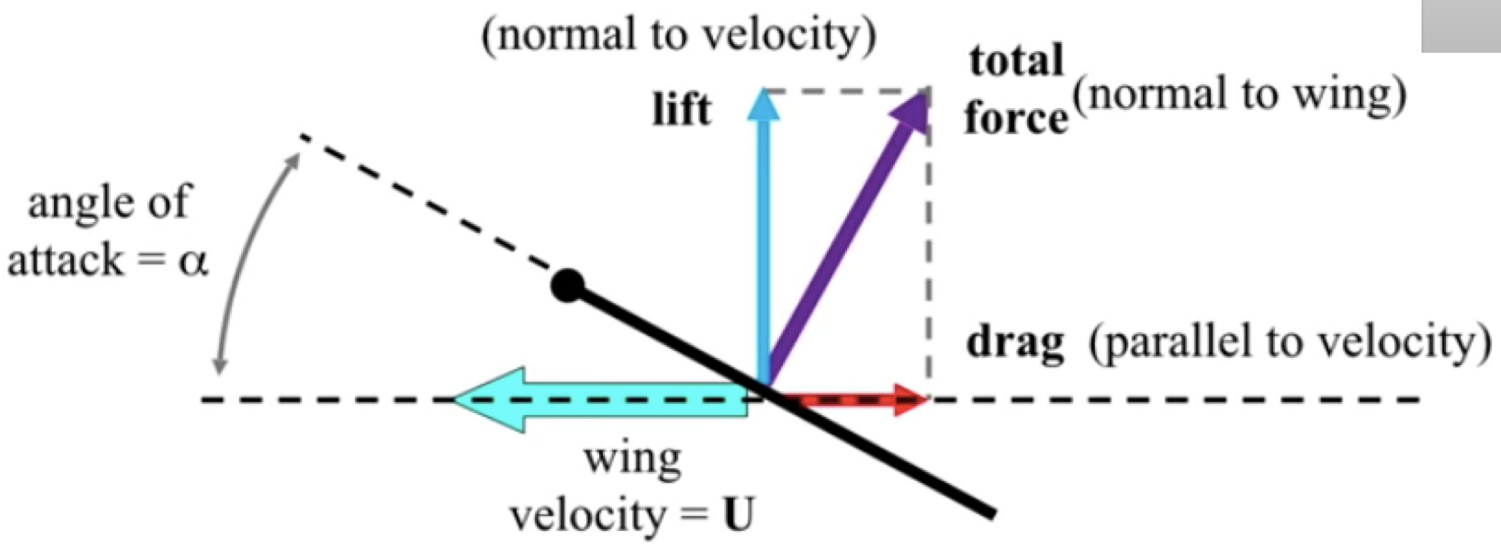


Basics of Insect Flight …



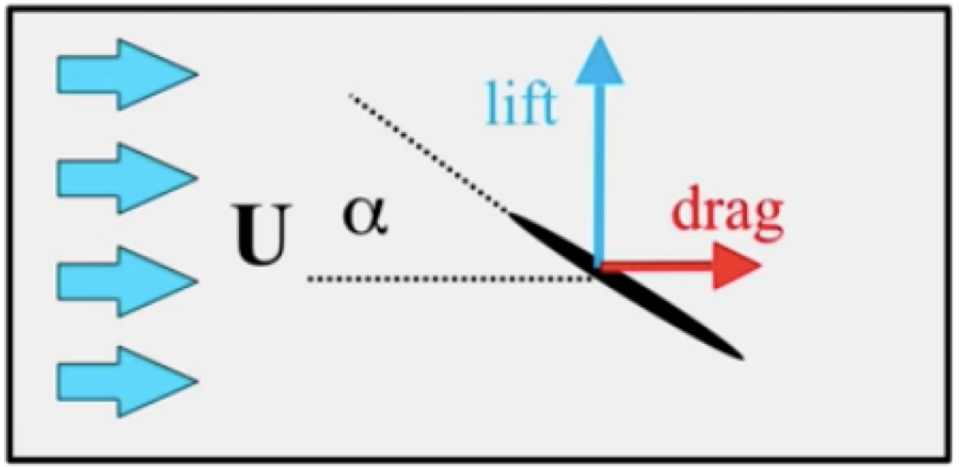


Again, life is hard
if you are small …

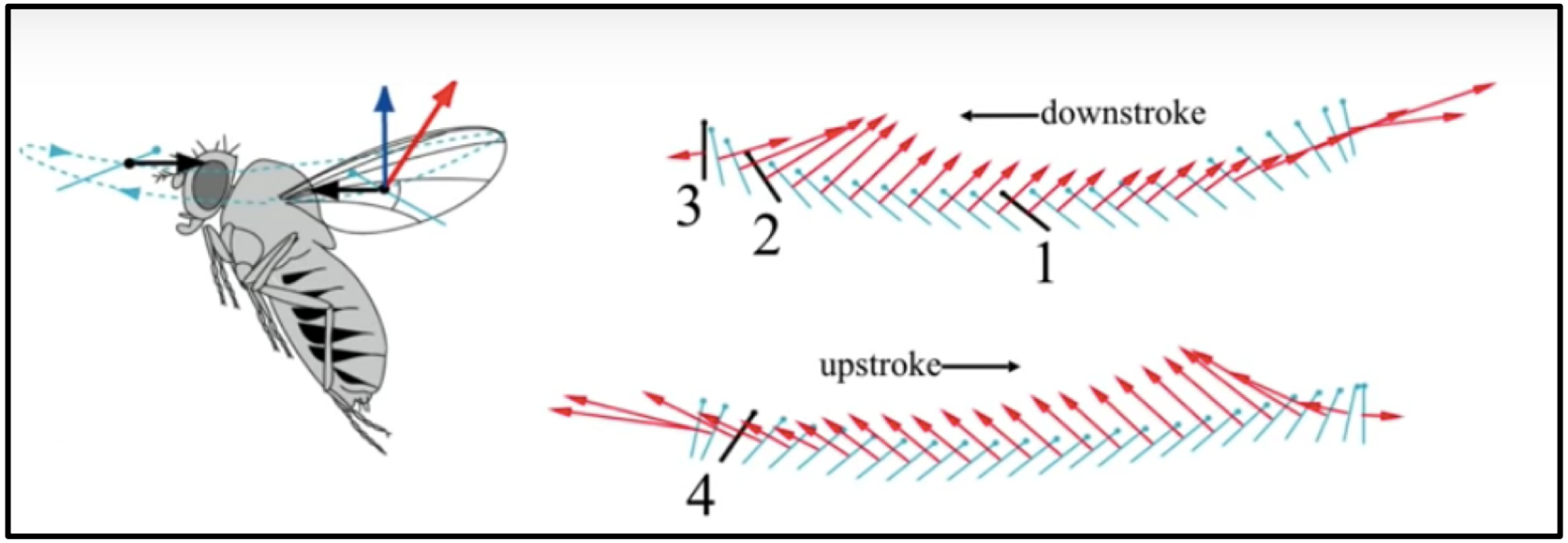


Experimental approach :-

wind tunnel



angle of attack = α

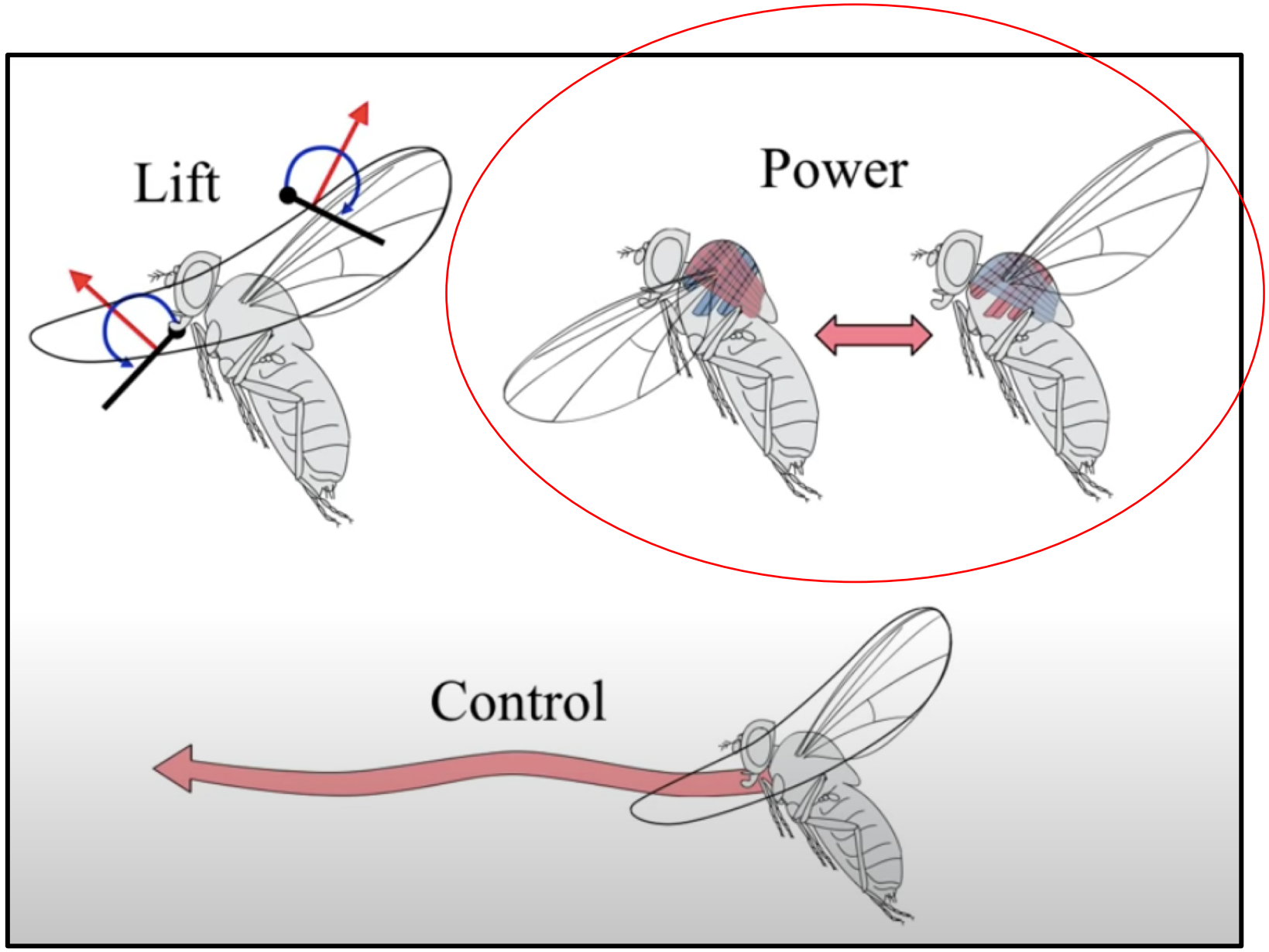


Time 24:00

[Dickiinson Ibiology Part2]

If you want to Fly …

We will look into this



But Flies don't just Fly …

- Male flies also flap their wings to generate a sound pattern that attracts female flies
- These two activities are similar, but there are subtle differences
- How are these two activities controlled by the brain ?

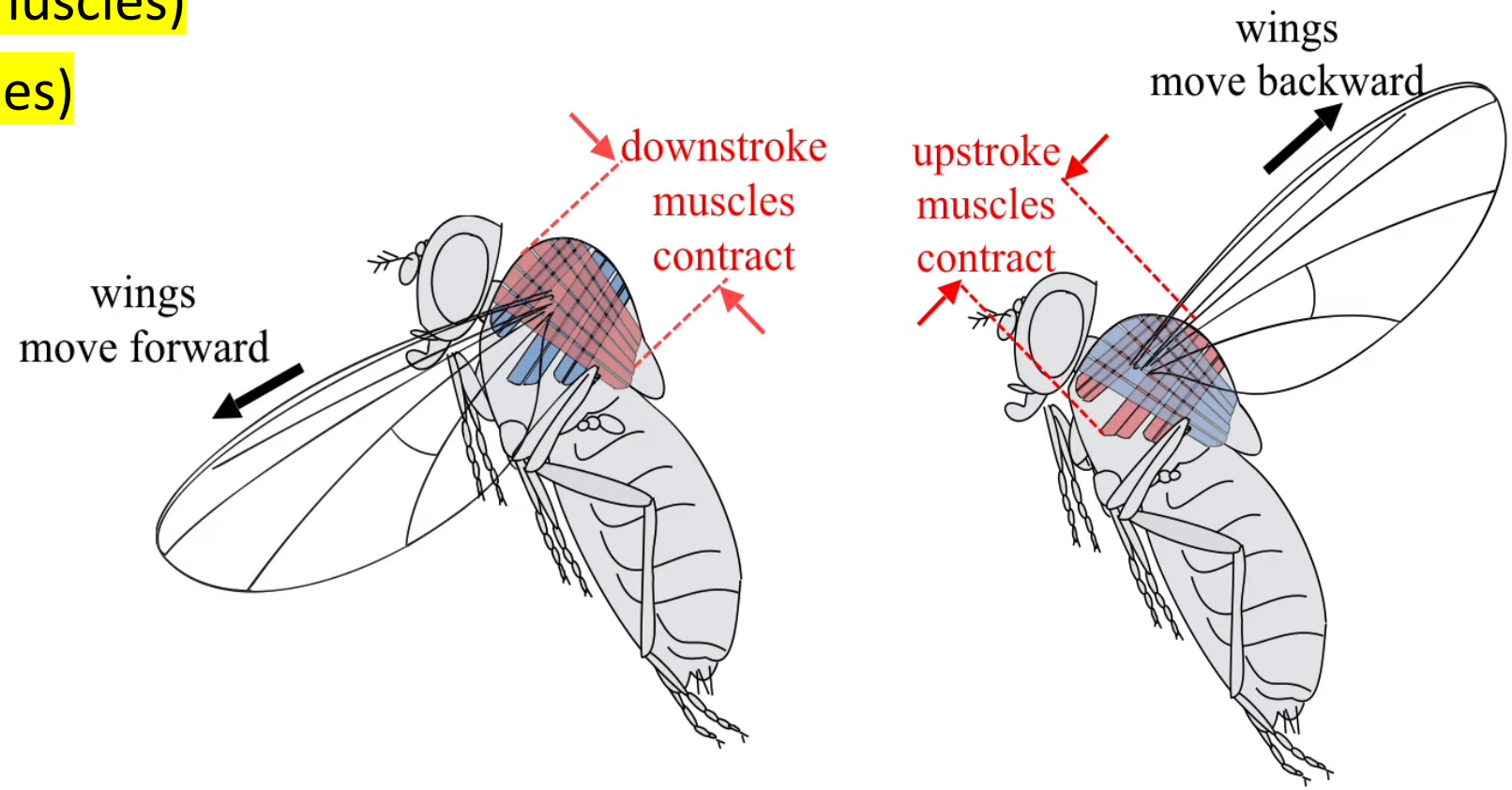
Multifunctional Motor Systems
(Recall Motor Neurons)

Two sets of muscles **stretch-activate** each other alternately for gross motion of wings :

DLMS (Dorsal longitudinal muscles)

DVMS (Dorsal ventral muscles)

Muscles of
THIS COLOUR
contract

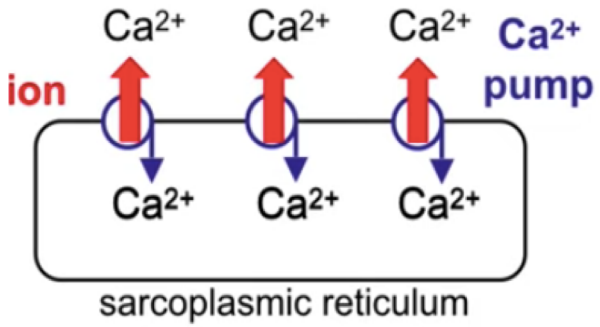


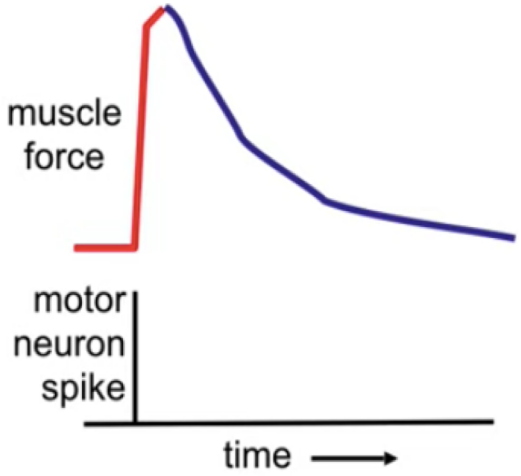
08:10 min (Dickinson iBiology Talk – 2)

Recall from previous lectures … How the brain controls muscles
Neuromuscular junction and activation of Myosin in muscle by Calcium release

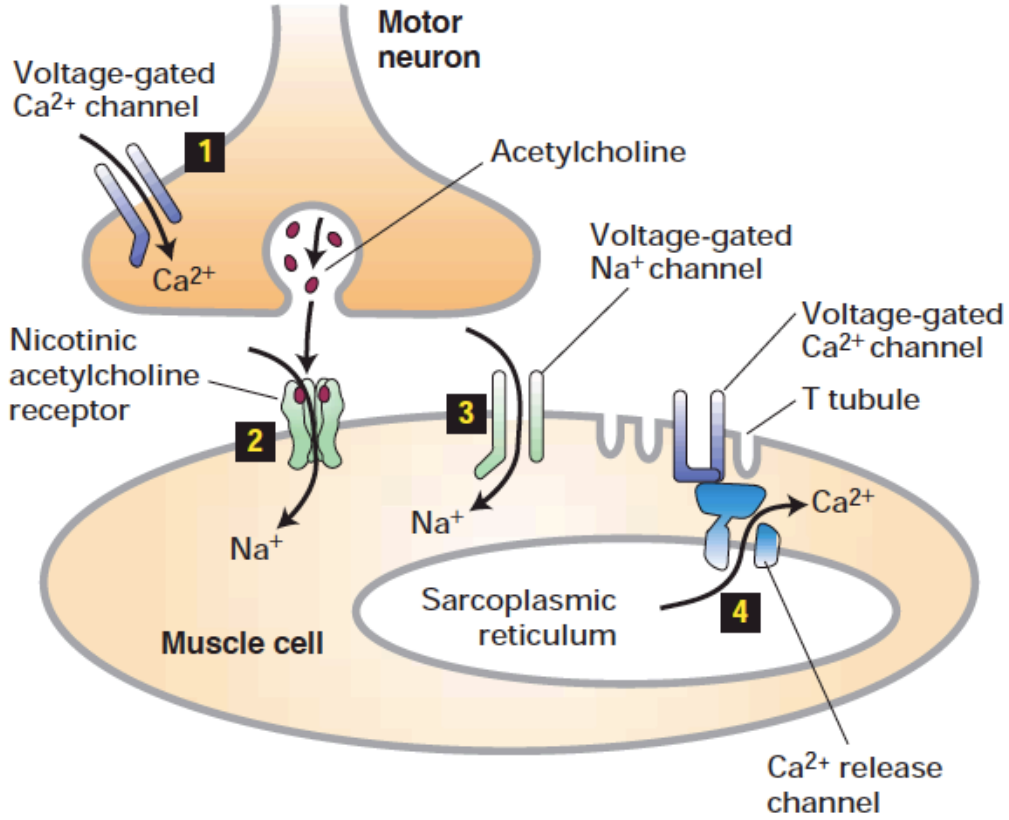
But Fly POWER MUSCLES are very small

→ Less space to accommodate Sarcoplasmic Reticulum
→ Must beat really fast to keep the fly in the air





Solution :- Don't depend on the brain fully for generating power



Calcium can be pumped out quickly to generate quick force

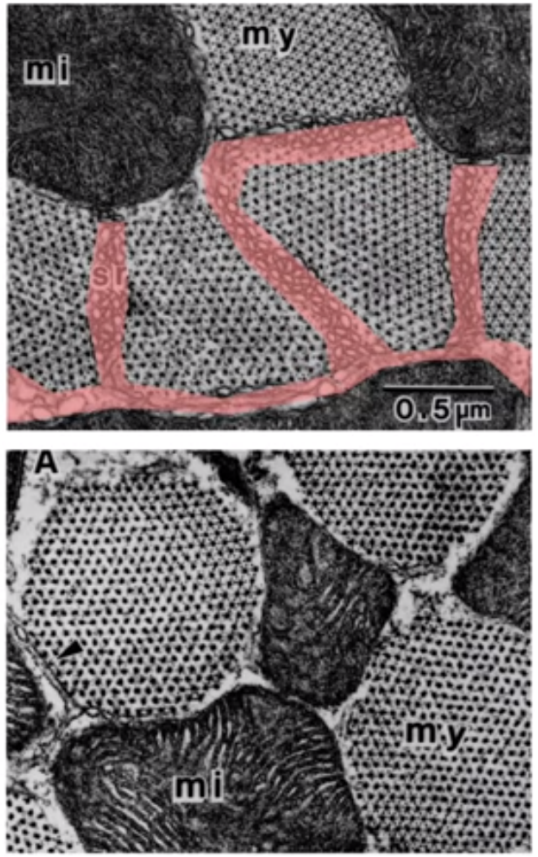
But, it diffuses all over the cell
→ Need time to pump it back into the Sarc. Reticulum
→ Difficult when the wings have to flap fast

DLMS & DVMS : Asynchronous muscles or Power Muscles … They are not controlled by Electrical Activity from Brain

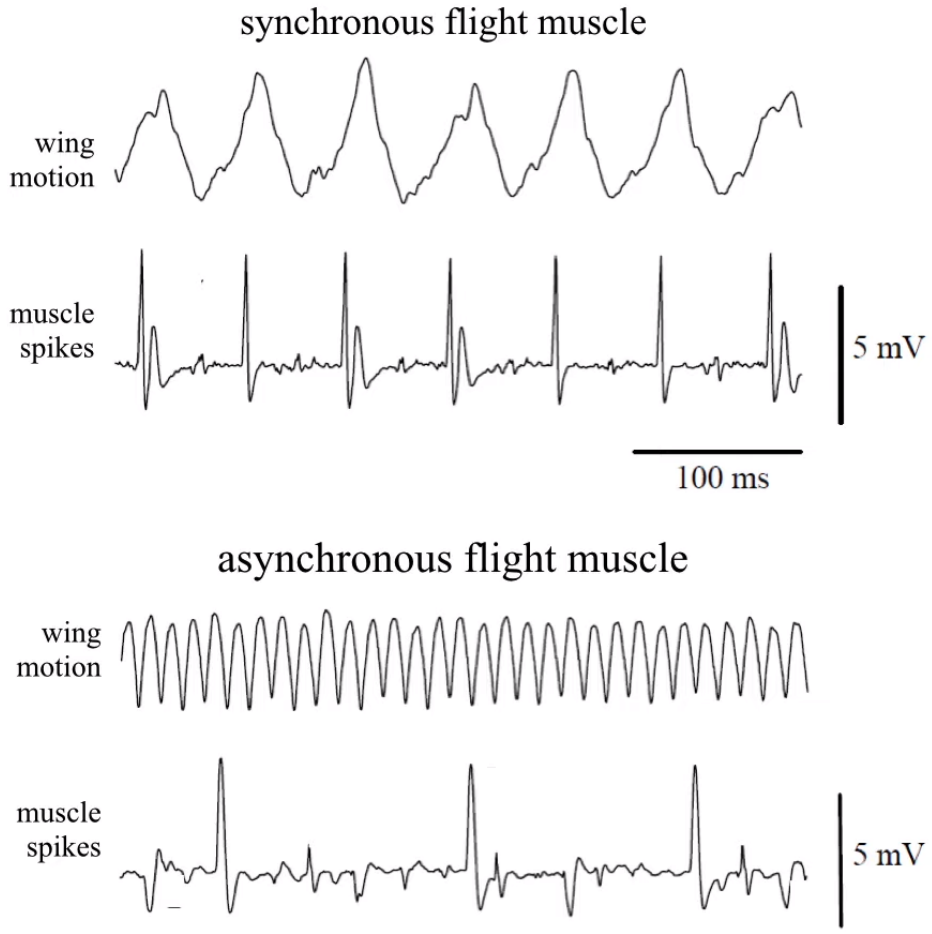
Synchronous twitch muscle

sarcoplasmic reticulum

Asynchronous power muscle



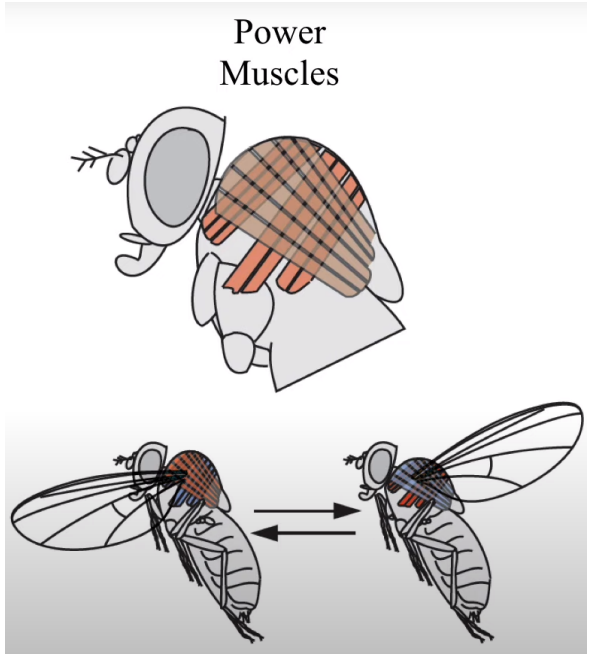
Adapted from Syme and Josephson. Integr. Comp. Biol. 2002



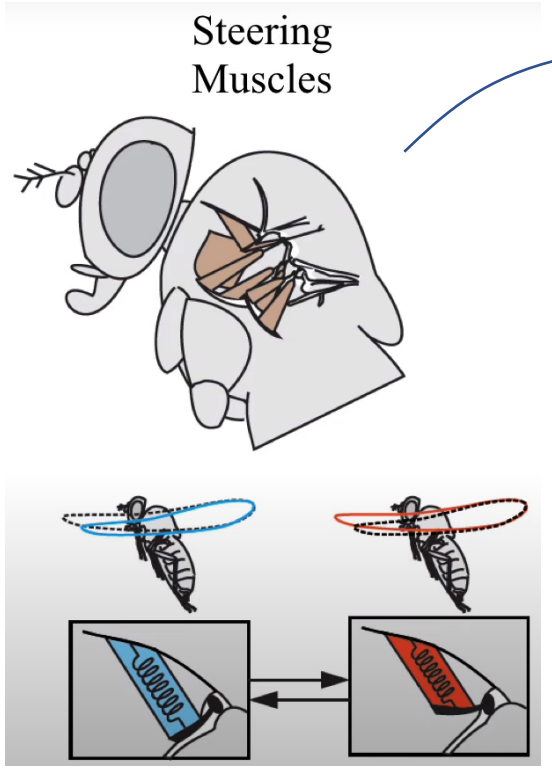
- Power muscle activity and Ca2+ release not synchronized with wing motion
- Adaptation to pack the muscle with more actomyosin complexes (= power) and also not depend on Ca2+ (which reduces speed)
- DLMS and DVMS are asynchronous muscles. They are the primary muscles that generate fast wing motion (power)

07:00 min (Dickinson iBiology Talk – 2)

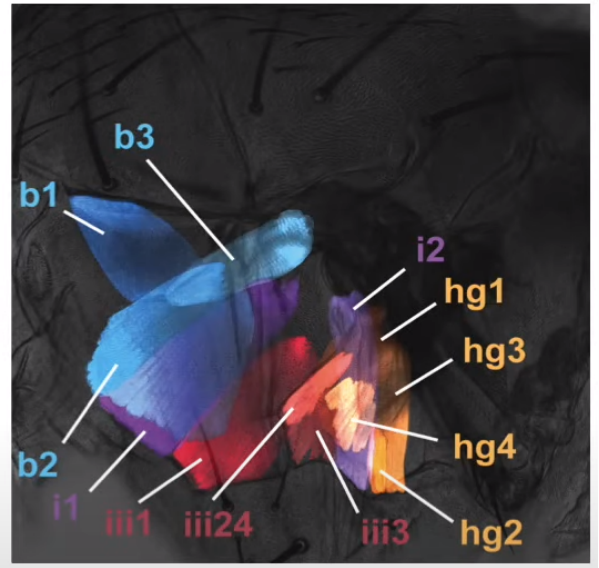
DLMS and DVMS motion is fine-tuned by
"Synchronous muscles" :- 12 smaller, so-called **Steering muscles** that are activated by motor neurons (the brain)



11:00 min (Dickinson iBiology Talk – 2)

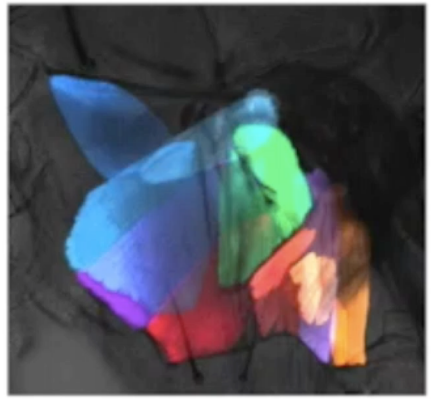


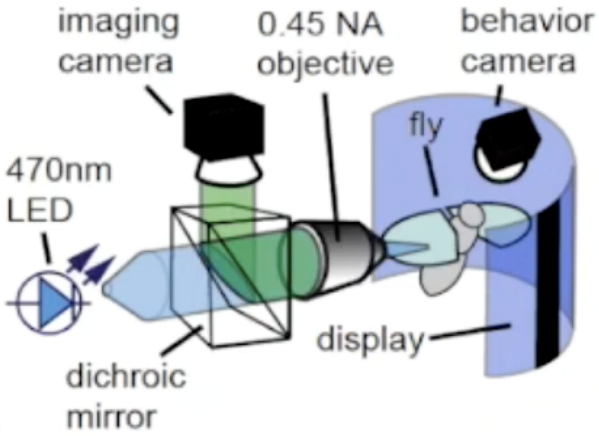
11:31

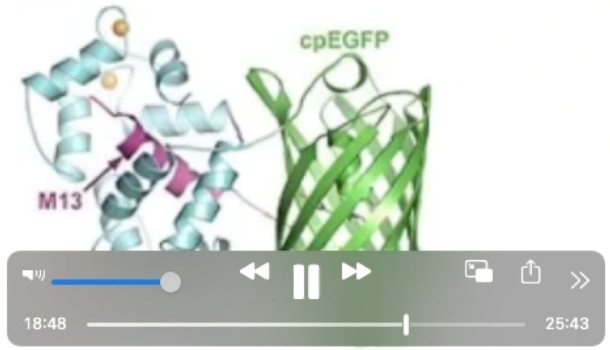


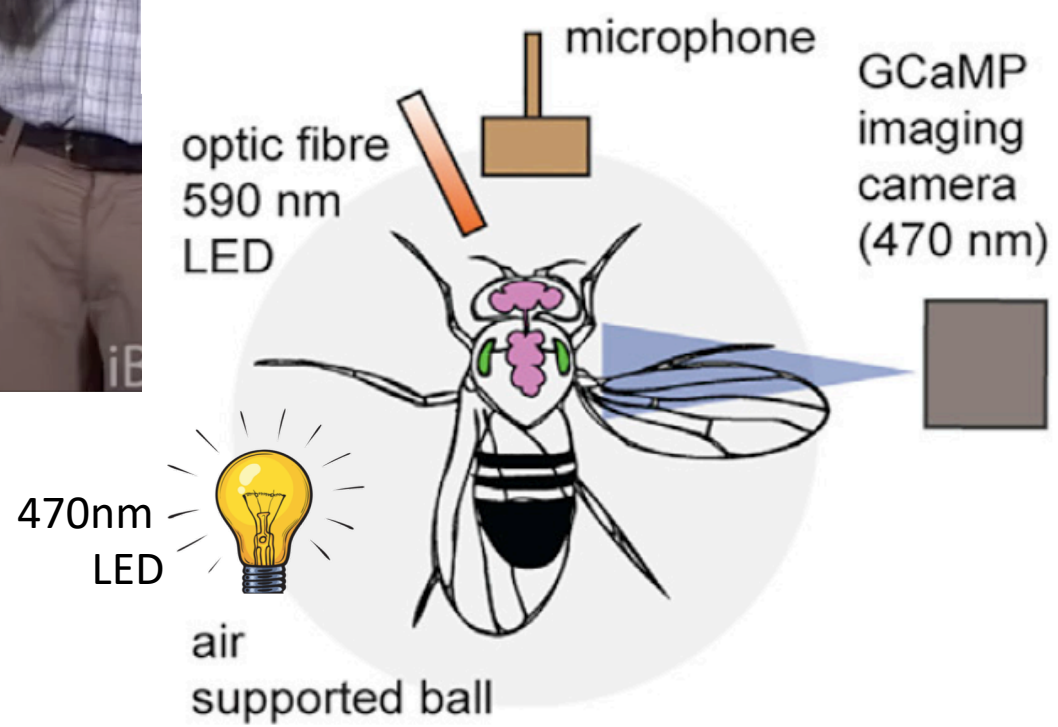
Are these Steering muscles functioning differently during Flight versus Song ?

Express a protein in the Steering muscle that fluoresces when Ca2+ levels are high
→ You can find out by imaging when the muscle is active
→ While imaging, record song and wing extension




imaging camera
0.45 NA objective
behavior camera
fly
470nm LED
display
dichroic mirror


cpEGFP
M13
18:48
25:43


microphone
optic fibre
590 nm
LED
GCaMP
imaging
camera
(470 nm)
470nm
LED
air
supported ball

Now, make the fly “Sing” ..

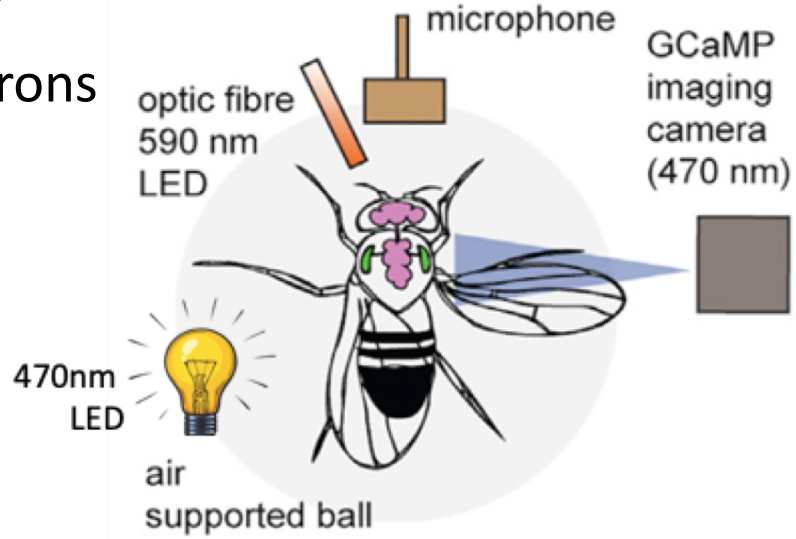
- Use one LED to Optically activate neurons that induce mating behaviour (i.e. to “sing”).
- Camera :- Record wing motion

  (Wing; 2nd row)
- Microphone:- Record audio

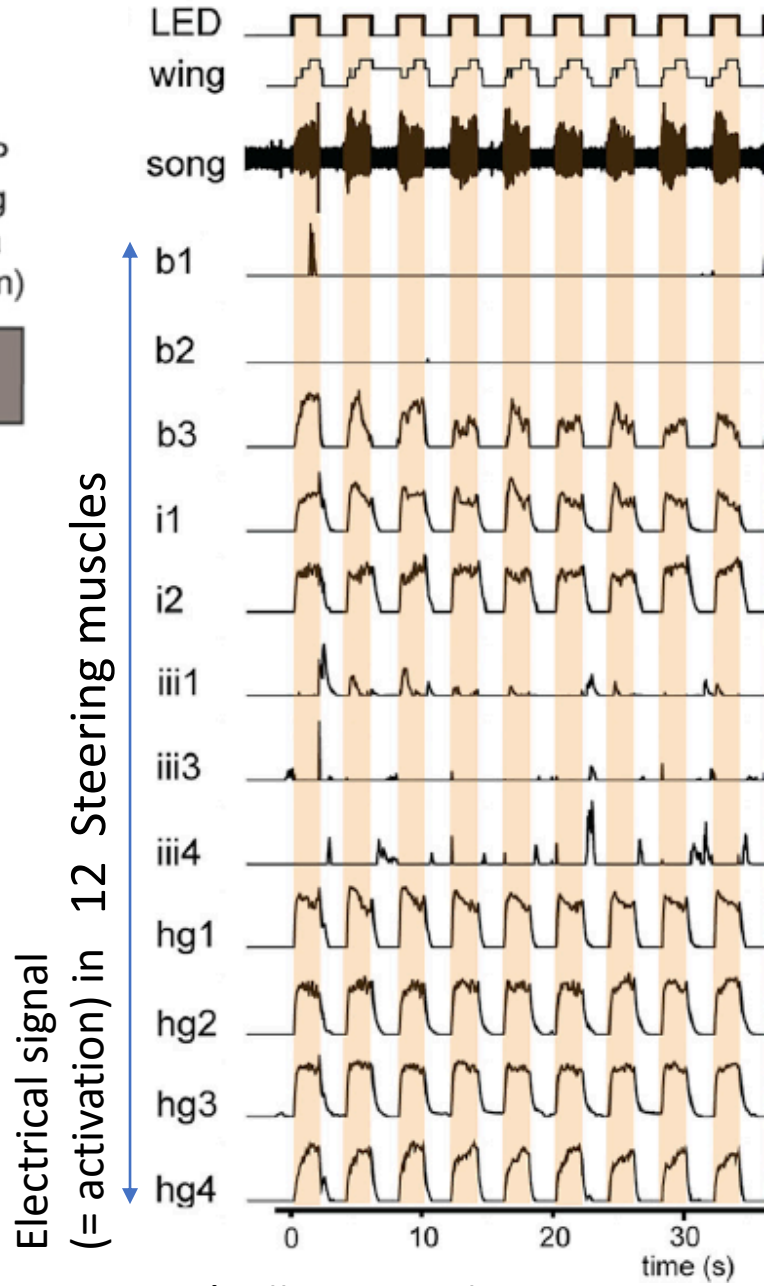
  (Song; 3rd row)
- Rows b1 to hg4 :- Measure Ca2+ levels (i.e. activation) in the Steering muscles using a fluorescent reporter of Calcium

Muscle activity and LED pulse (Song) were :-

- Strongly correlated with i1 and hg1–4 muscles
- Variable in i2 and the iii1, 3, 4 muscles
- No Correlation in b1, b2 muscles



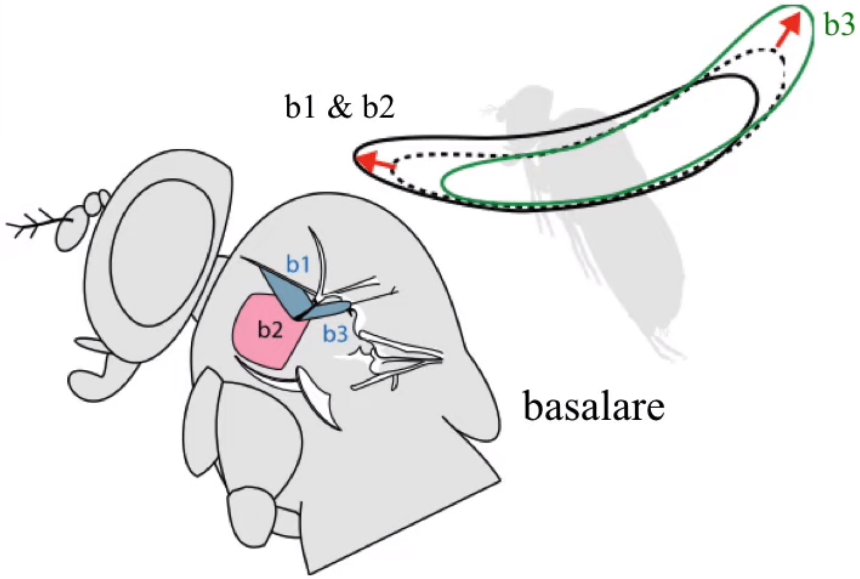
LINK to paper



O’Sullivan et. al

Now, make the fly fly …

- Puffs of Air in specific pattern to induce flight-like wing motion
- Direct electrode based measurement of Electrical activity and correlation to wing motion
- Activity of b1, b2 and b3 muscles is highly correlated with wing flapping during flight



20:40 min (Dickinson iBiology Talk – 2)

Summary :-

- Asynchronous muscles (DLMS and DVMS) used to generate wing motion
- Wing motion (of different types) used for Song as well as Flight
- Subtle motion/orientation of wings controlled by 12 Steering muscles (Synchronous)
- Steering muscles that Control Song and that Control flight appear different

Is there a hierarchy between Song and Flight?

Can and/or Should Flies :-

a) Sing when Flying ?

b) Fly when Singing ?

- Optogenetically activate a Song Motor Neuron
  - When fly is not flying :- It Starts Singing
  - When fly is flying :- No Song, they keep flying normally

From O'Sullivan et al. :- "song and flight motor patterns are mutually exclusive and that the flight mode of wing MN usage is supported by a biomechanical configuration and a stable pattern of circuit activity that cannot be easily disrupted by a descending song command."

TAKE-HOME MESSAGE :-
SELF-PRESERVATION BEFORE REPRODUCTION

EndSem Exam. 14 June (Wed). 9:30AM – 12:30PM

1) Questions from part taught by R. Mallik (Lecture 1 – Lecture 11)
2) 90% weightage to the part taught by R. Mallik (10% to Quiz)
3) Questions Mix of Descriptive, Calculation oriented, MCQ, True/False, Fill in the Blanks, “Correct the Mistake”.
4) Calculator allowed. Other Electronic devices and Cell Phones Strictly Forbidden.
5) You can bring ONE A4-sized sheet with any Information you feel is relevant. You can write on both sides.
6) Question paper to be returned with answer sheet.
7) You will be provided Model answers after the Exam.