FLYING AS AN INSECT

Angelique Paulk

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Objectives

- What is the structure of the wing?
- How can insects fly?
- What is the neural wiring allowing insects to fly?

The evolution of the wing

- The evolution of the wing is a hotly debated topic
- The evolution of the wing may have come from the notum (top of the insect), the pleurum (the side sclerites) from the leg area (near the coxa).

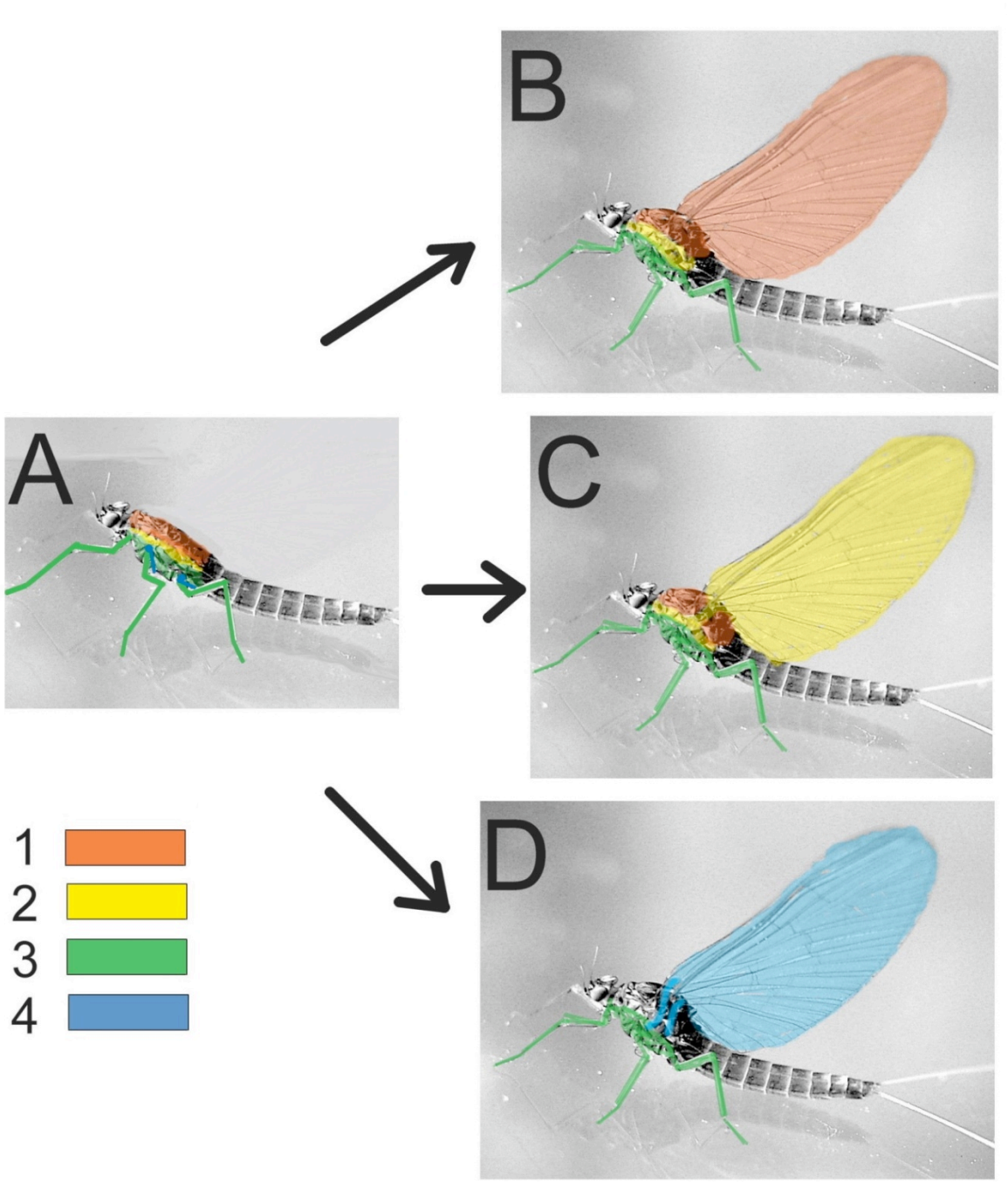
A Hypothetical wingless ancester

B Hypothetical insect with wings from notum (Paranotal-theory)

C Hypothetical insect with wings from Pleurum

D Hypothetical insect with wings from leg exit (Epicoxal-theory)

1 Notum
2 Pleurum
3 Sternum with legs
4 Exit of leg



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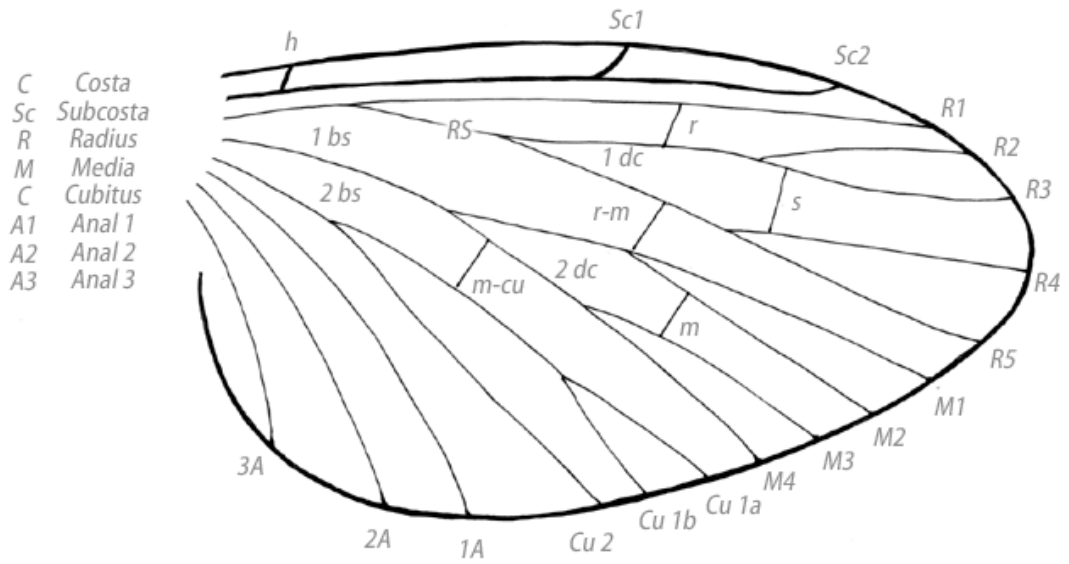
The wing

- The basic structure of the wing is generally a series of veins, which has a basic design:



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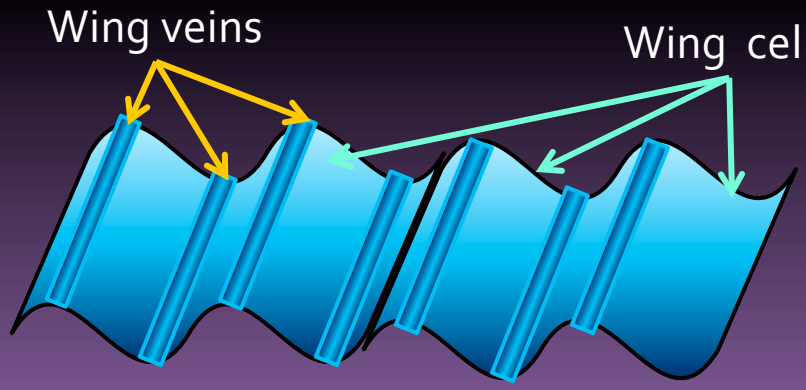
- The wing venation allows for structural stability, which involves alternating between wing veins and cuticle between them, resulting in an accordian-like effect, which can strengthen the wing



http://en.wikipedia.org/wiki/Insect_wing

The wing structure: diverse designs

Wings can be very different, from massive, complex wings as in the stick insect (left), to single, streamlined wings, such as flies (below)

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Arthur Chapman Wikimedia Commons

The wing structure: diverse designs

- In the smaller insects, such as thrips and aphids, the wings can be reduced to a few veins or are even feathered (as in thrips) or scaled (such as the mosquito below).
- These insects are so small that moving through the air can be more like swimming through the air because the forces are very different

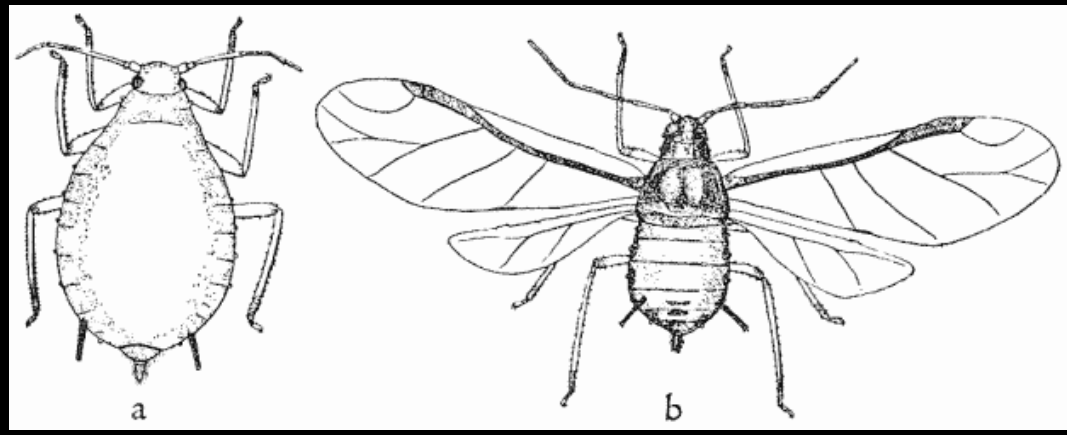
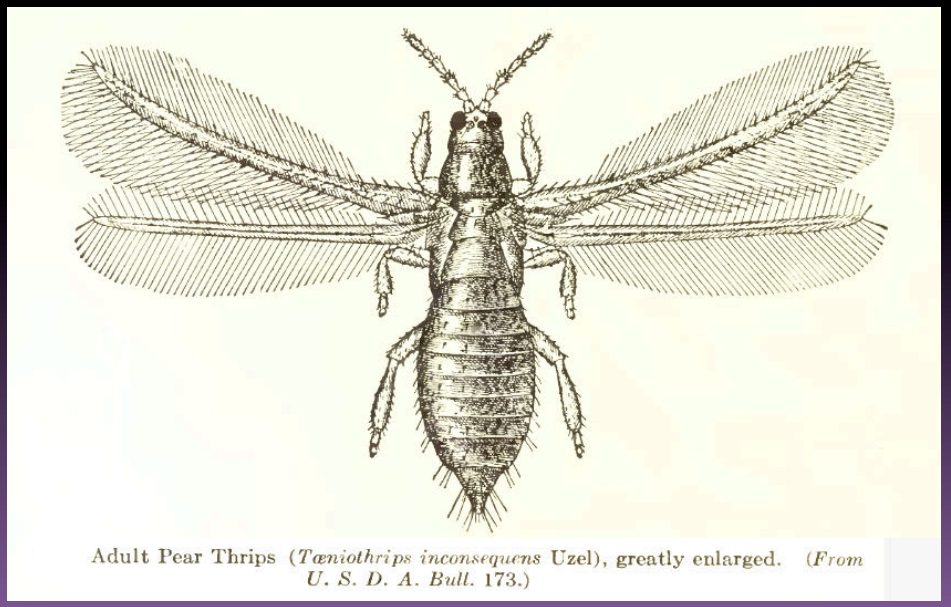


Figure 6 from The Life-Story of Insects by George H. Carpenter Wikimedia Commons


Adult Pear Thrips (*Tæniothrips inconsequens* Uzel), greatly enlarged. (*From U. S. D. A. Bull.* 173.)

H T Fernald Wikimedia Commons

Wing folding

Several insects, such as beetles and hemipterans fold their wings, which involve hinging the middle of the wing or folding it along specific veins or creases

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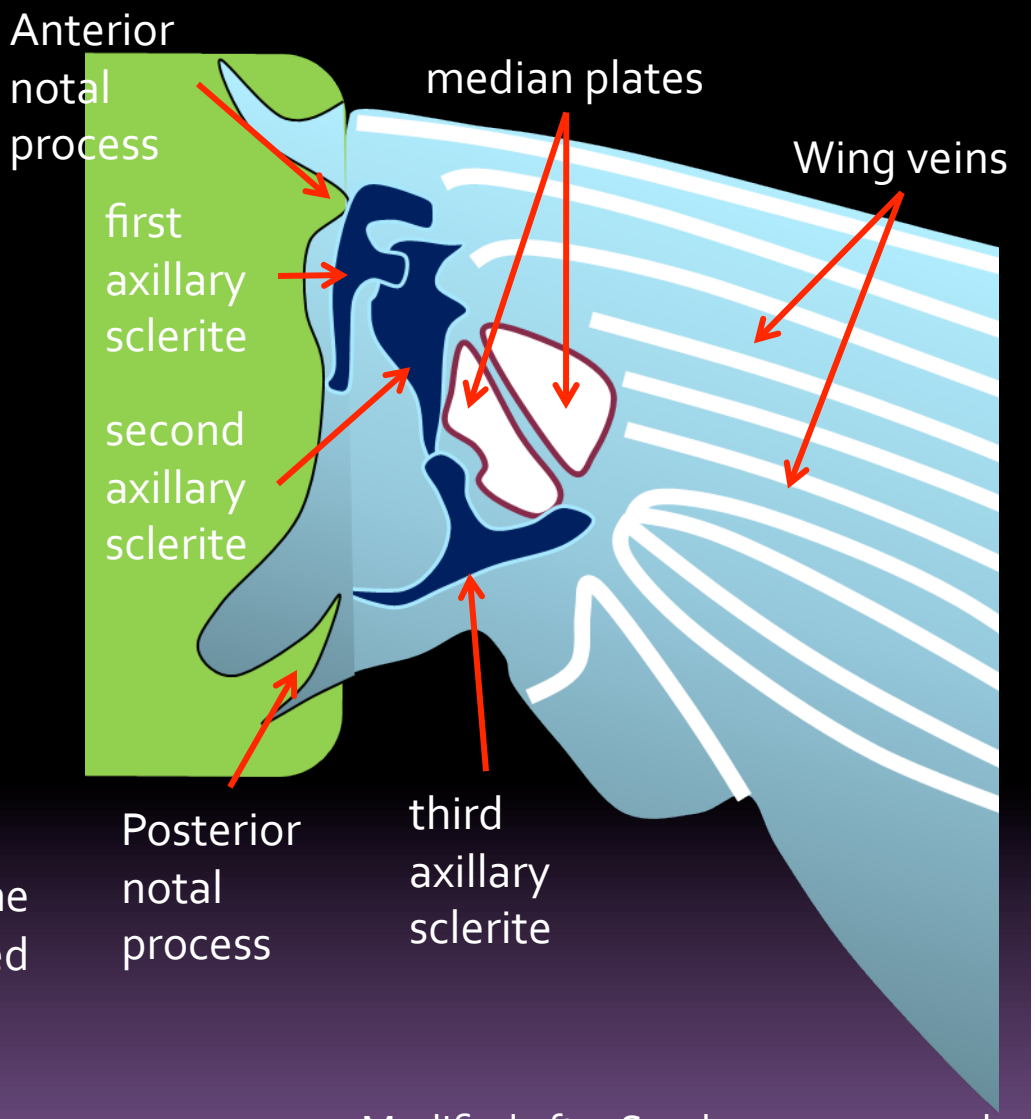
Wing attachments to the thorax

- Check out the website below on the anatomy of the thorax: http://www.earthlife.net/insects/anat-thorax.html
- The wing attachments to the thorax involve a complex series of sclerites embedded in membraneous cuticle.
- The flight musculature can attach directly to these sclerites, which can change the angle of the wing, with the front edge of the wing being deflected downward or upward

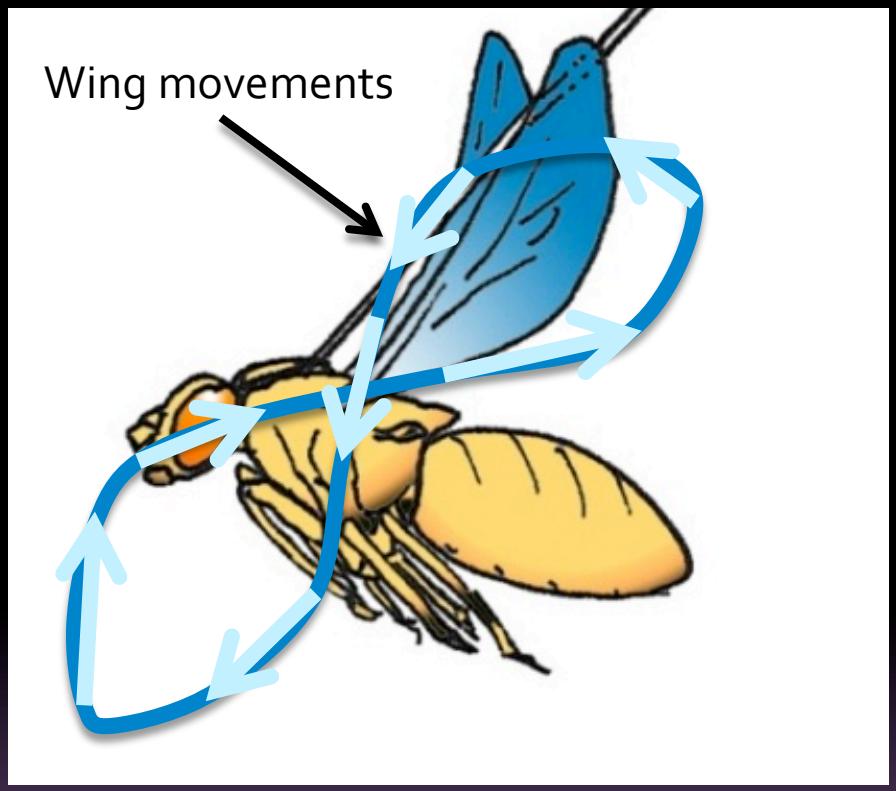


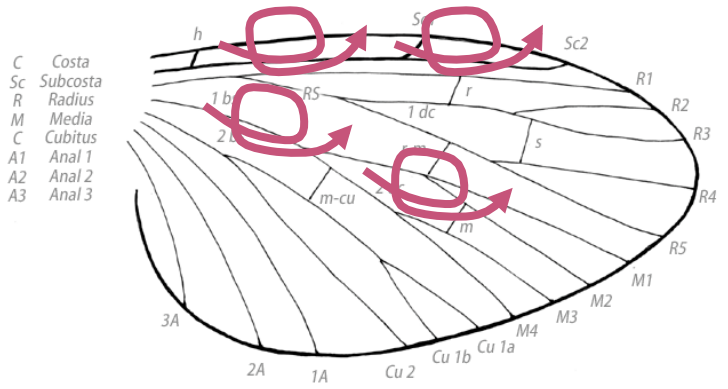
Modified after Snodgrass, 1955, and Chapman, 1998

http://en.wikipedia.org/wiki/Insect_flight

http://www.nurseminerva.co.uk/adapt/insect.htm

The wing structure: How it flaps

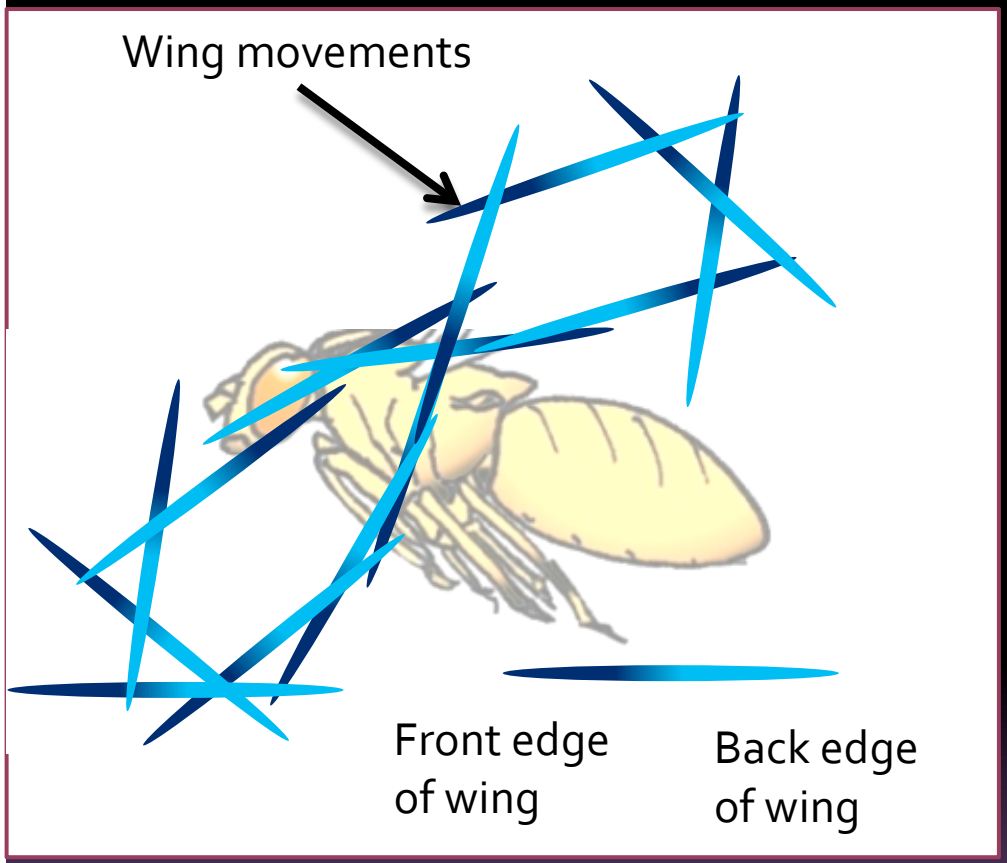


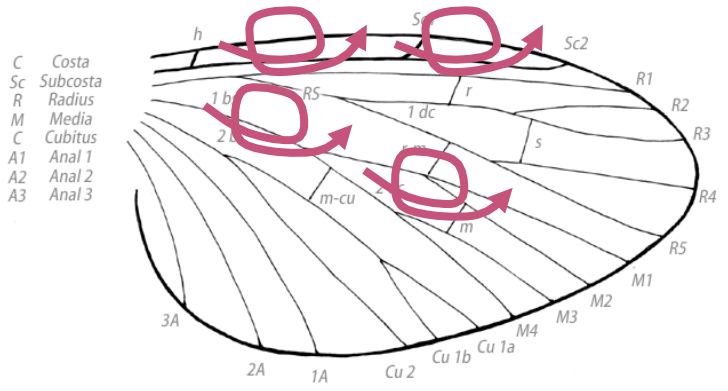


- The wings can generally move around along a figure eight, where the wings move back, are flipped upside down, and rotates around so they are right side up, generally moving across along a figure eight path.
- Throughout this path, fine vortices of air move along the wing veins, allowing the air to move faster over the top of the wing, resulting in lift
- Other ways that insects fly is the clap and fling, which is seen in butterflies and moths

Check out the website below on insect flight for more details:
http://en.wikipedia.org/wiki/Insect_flight

The wing structure: How it flaps





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The wing actually flips around, such that the vortices can be created along its surface with each flipping of the wing, as indicated in this side view of the wing.

Insects can flap their wings up to and beyond 400 beats per second, though this occurs mostly in flies.

Check out the website below on insect flight for more details:
http://en.wikipedia.org/wiki/Insect_flight

Wing movements through the air

- As the wings move through the air flapping, the wings are deflected through the air.
- You can see it in these two high speed movie of flies flying:

  Flies flying:
  http://www.arkive.org/house-fly/musca-domestica/video-00.html

  Fly flying

- Check out the movie below to see how a wing is deflected in the air from the laboratory of Tom Daniel:

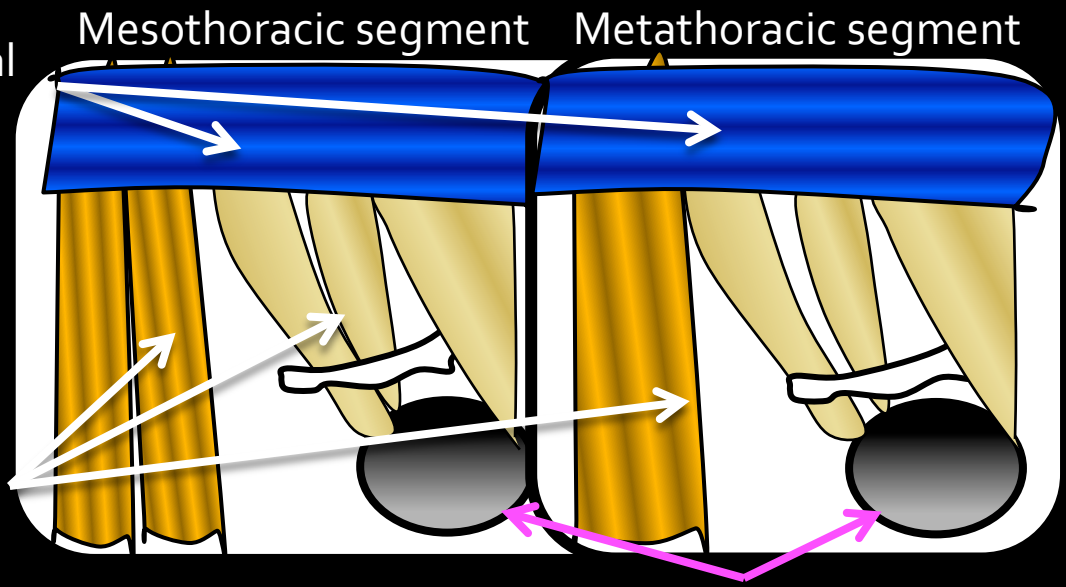
  Flapping wings
  http://faculty.washington.edu/danielt/Wingmovies.html

- When the wings are moved under different conditions, such as helium, the wing does not move in the same way, in that, in air, the wing can form the vortices

  Under different air conditions
  http://faculty.washington.edu/danielt/vacbox.html

Thoracic wing musculature

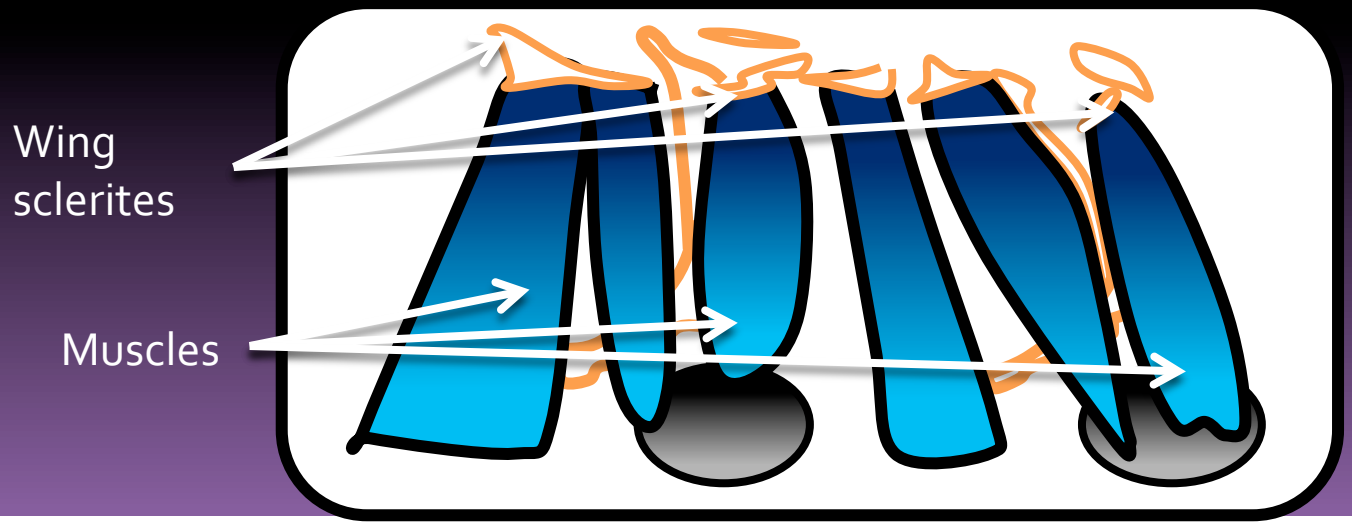
Indirect flight muscles



Adapted from Chapman (1998)

The musculature of the ***indirect*** flight muscles are from the base of the coxa or the thorax to the top of the thorax or between apodemes within the dorsal surface of the thorax, thereby not connecting directly to the wing sclerites.

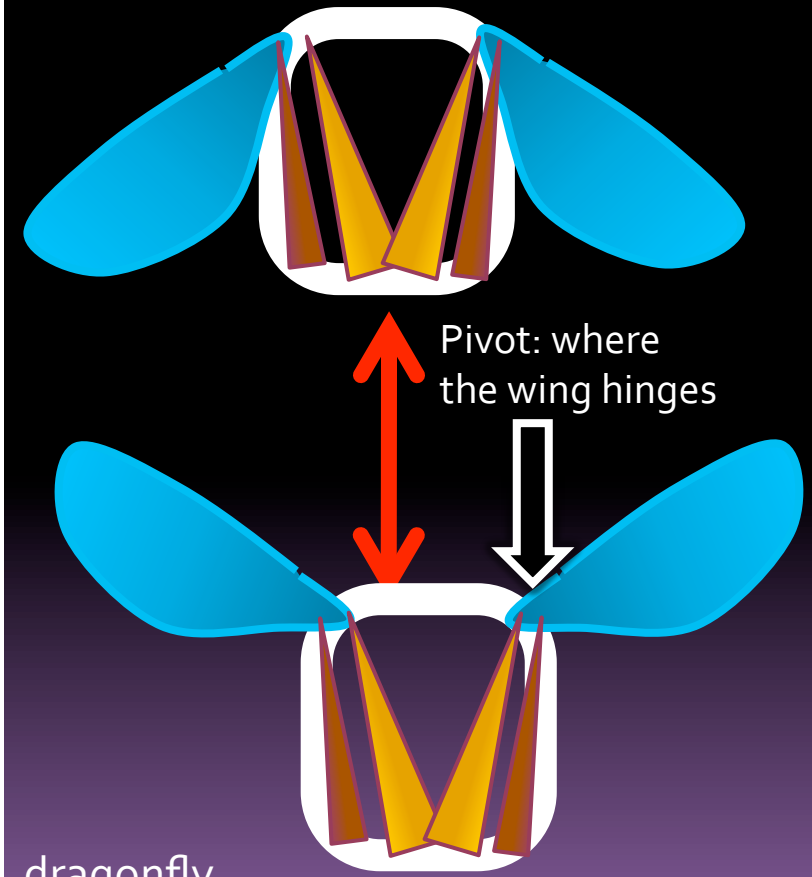
Direct flight muscles

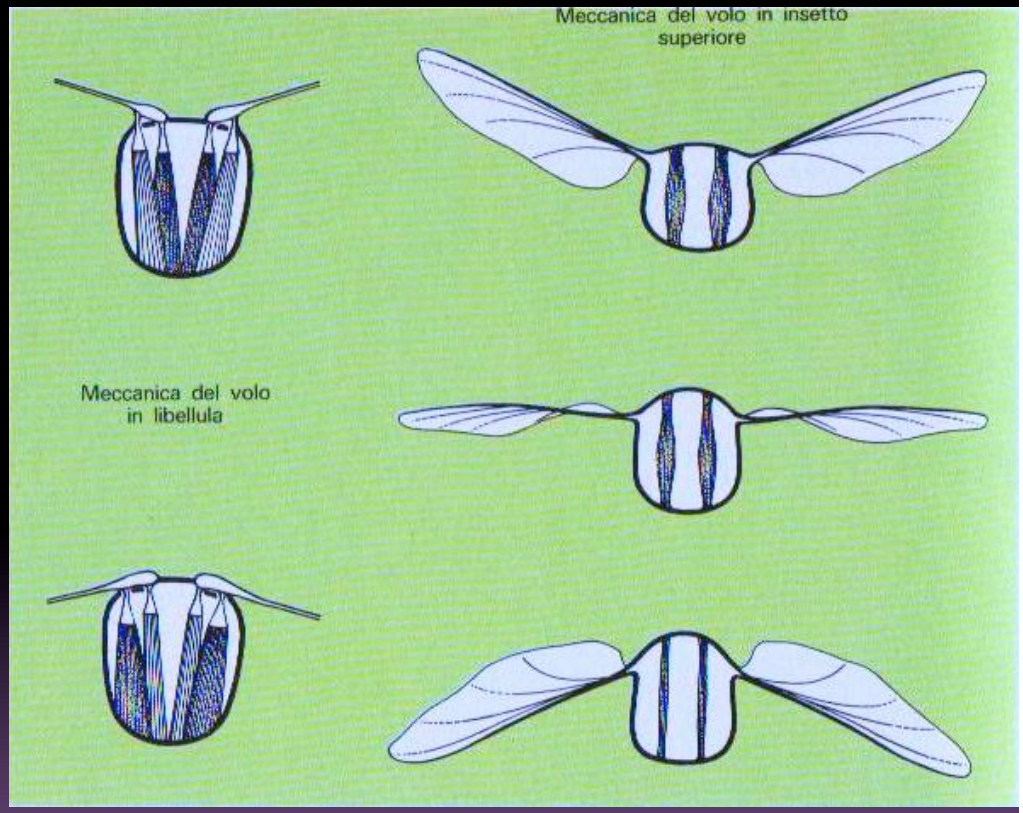


The musculature of the ***direct*** flight muscles are from the base of the coxa or the thorax to the wing sclerites surrounding the wing attachment, which can provide direct control of wing movements.

Wing musculature: direct flight muscles

Frontal view





Piero Sagnibene (Posted by --gian_d 19:48, 3 January 2007 (UTC))

dragonfly
http://www.arkive.org/emperor-dragonfly/anax-imperator/videos.html

Direct flight: Odonata

Dragonflies also move their wings in an alternating pattern, which is controlled through direct flight musculature

http://en.wikipedia.org/wiki/GNU_Free_Documentation_License Taken by Firooo2, flagstaffotos.com.au

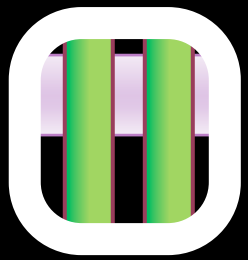
Wing musculature: indirect flight muscles

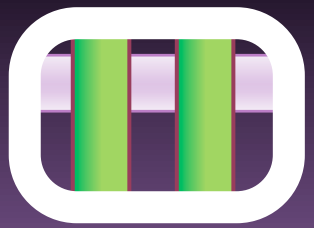
Side view

Frontal view

Dorsal longitudinal muscles

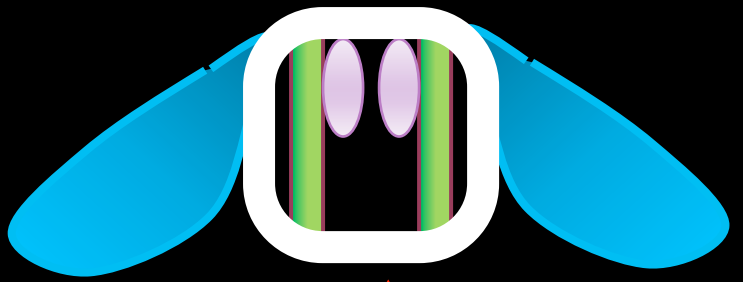
Dorsoventral muscles

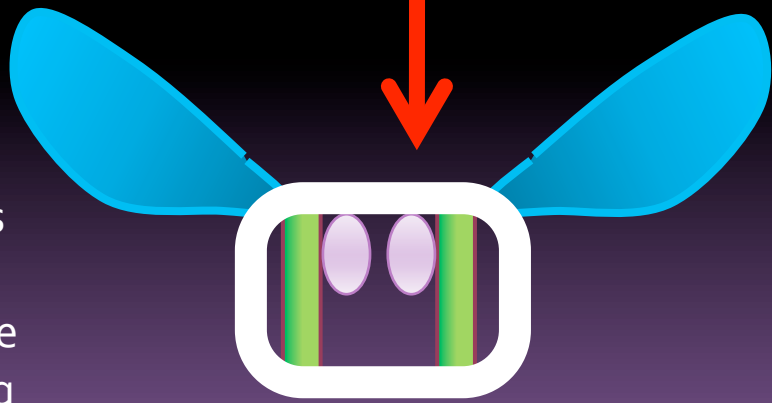




Contract dorsal longitudinal muscles: compress the thorax front to back, causing the wings to lower along their pivots

Contract dorsoventral muscles: compress the thorax top to bottom, causing the wings to raise along their pivots



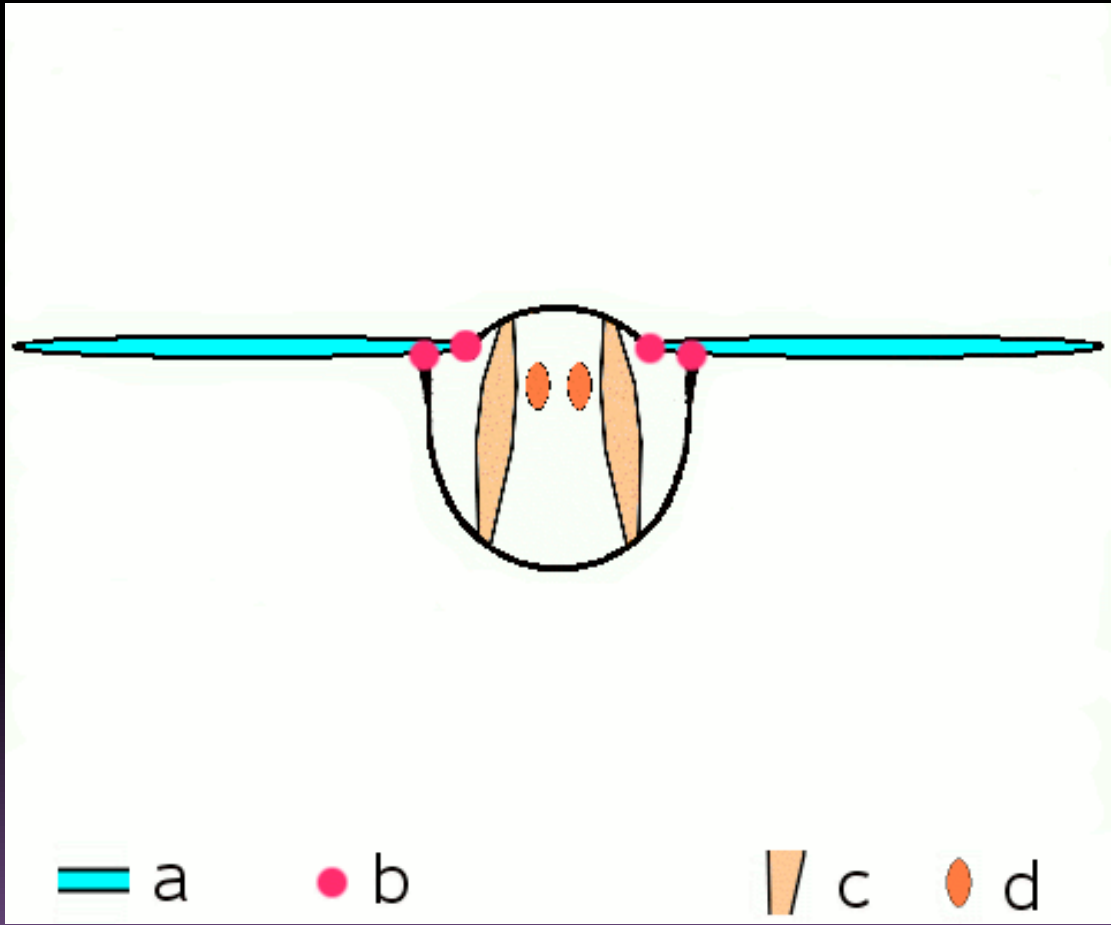


Wing musculature: indirect flight muscles

Basic motion of the insect wing in insect with an indirect flight mechanism.

Scheme of dorsoventral cut through a thorax segment with wings

a wings
b joints
c dorsoventral muscles
d longitudinal muscles



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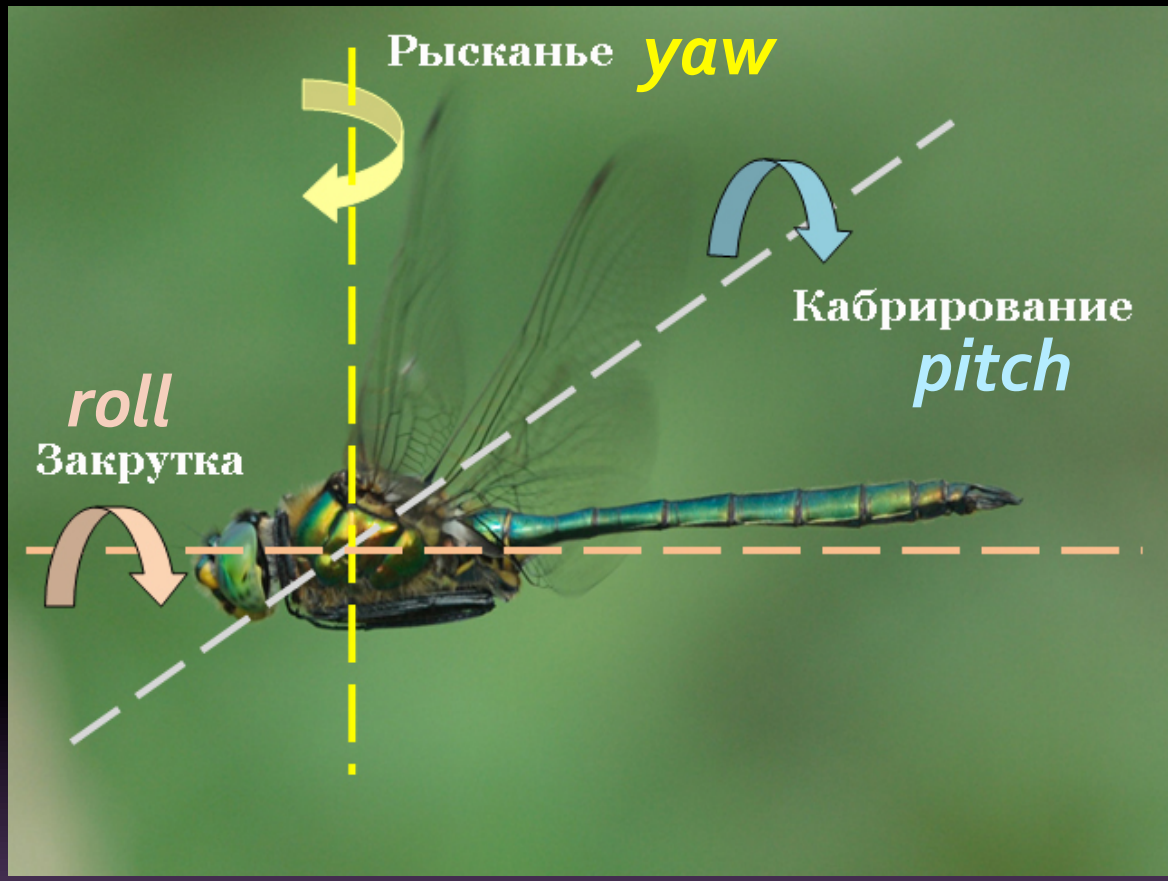
Dimensions of movement in flight

- Insects can rotate through three different axes, which includes pitch (up/down), yaw (side to side), and roll (roll around the front)
- In addition to these three dimensions of movement, insects can move forward (translate), and slip sideways
- Considering these different types of movements, insects have to detect when changes in movements along the wing and wing base as well as use visual feedback (see Module 15)



Anaxibia Wikimedia Commons

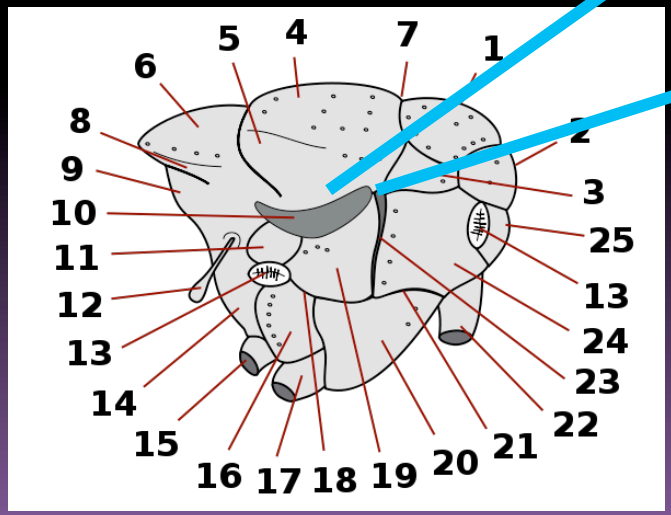
http://en.wikipedia.org/wiki/Insect_flight

Sensory input from the wing

- On the wing itself, there are campaniform sensilla, setae, hairs, and sensilla to detect deflections of the wing.
- There are nerves mostly in the base or in the thicker veins of the wing.
- Other sensory inputs of the wing are at the base around the wing and around the sclerites,which include campaniform sensilla, setae, and chordotonal organs

Setae and sensory hairs

campaniform sensilla



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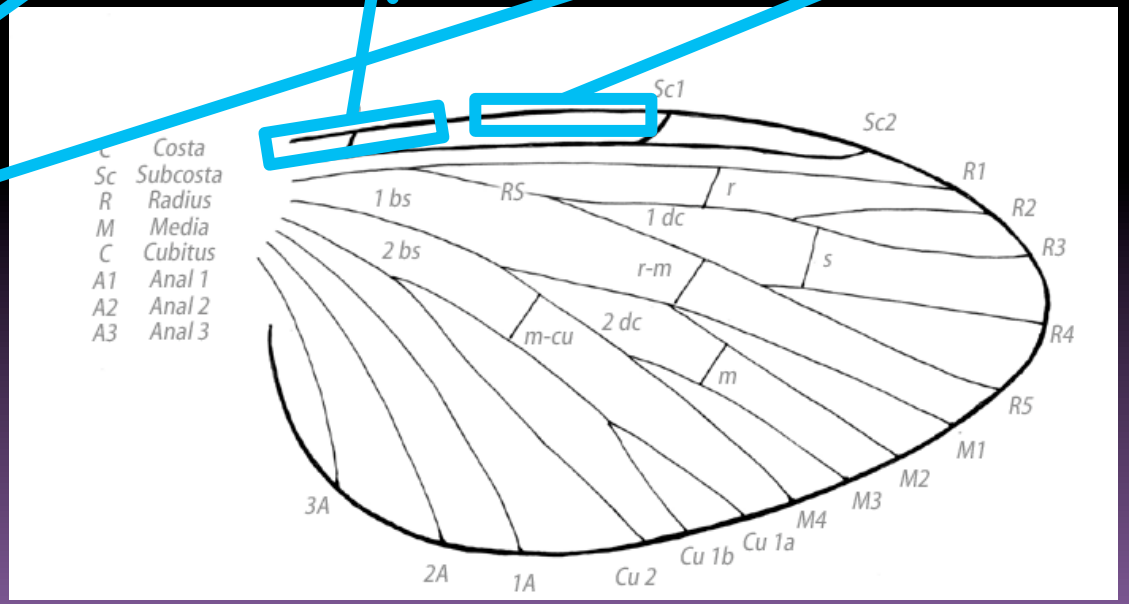

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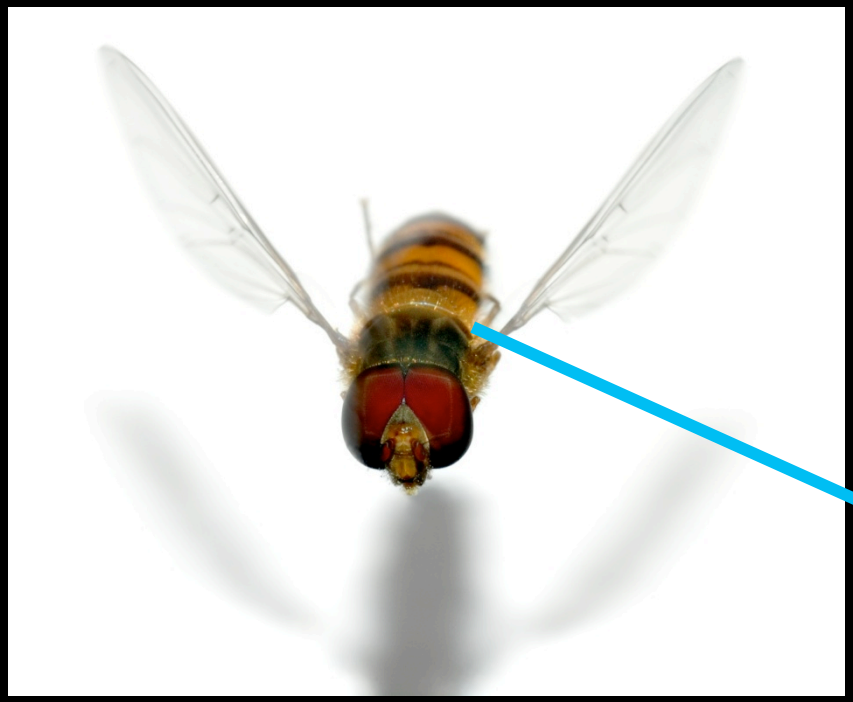
The halteres: what they do



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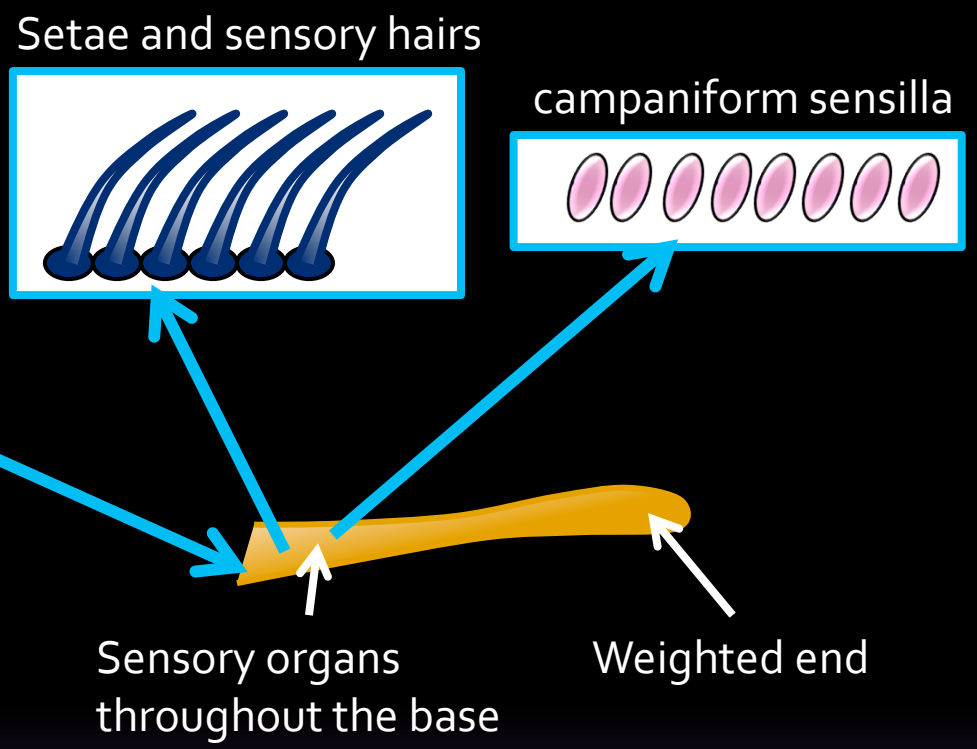
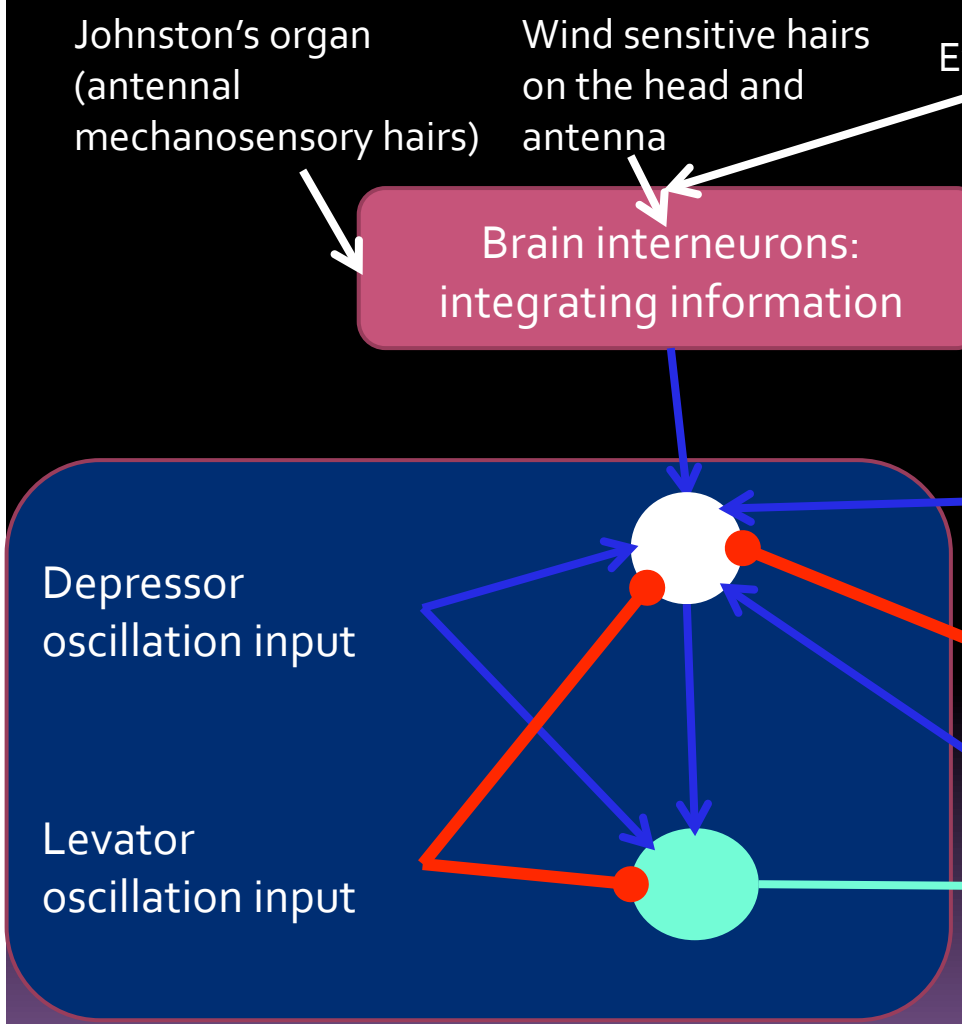


- Halteres are a modified pair of wings, which is on the metathorax in the order Diptera and on the mesothorax in the order Strepsiptera
- The halteres are gyroscopes, where they can detect accelerations about the yaw axis
- The halteres flap at the same frequency of the wings (up and down)
- When the insect suddenly moves in the yaw direction, the haltere is deflected, which is detected by the mechanosensory organs at the base of the halteres

Wiring the flight circuit



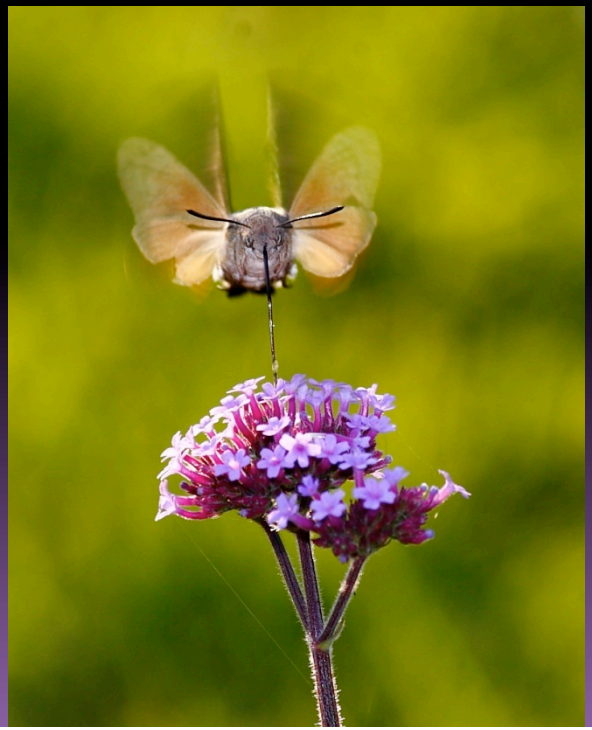
The flight circuit involves a complex integration of information from the sensory organs on the head and on the thorax as well as input from oscillators in the thoracic ganglion, which alternate between depressing or elevating (levator) the wing.

Flight stabilization

- With the help of halteres, mechanosensory organs, visual feedback, and various control mechanisms, insects can have incredible control of flight.
- In the two videos below, hawkmoths (family: Sphingidae) can show incredible hovering flight, which can adapt based on visual and mechanosensory feedback:

http://commons.wikimedia.org/wiki/File:Macroglossum.stellatarum.video.ogg

http://faculty.washington.edu/danielt/tracker.html



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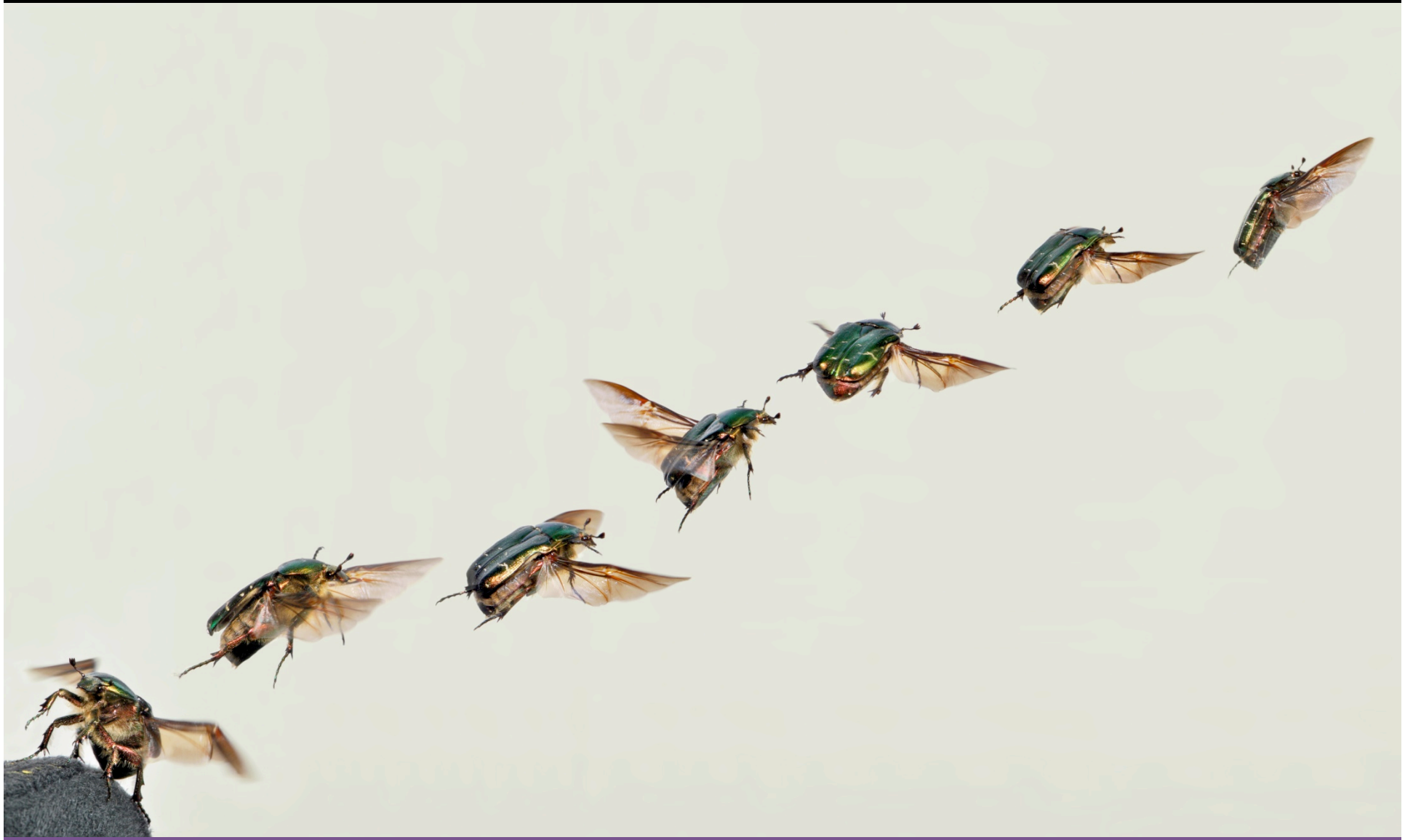
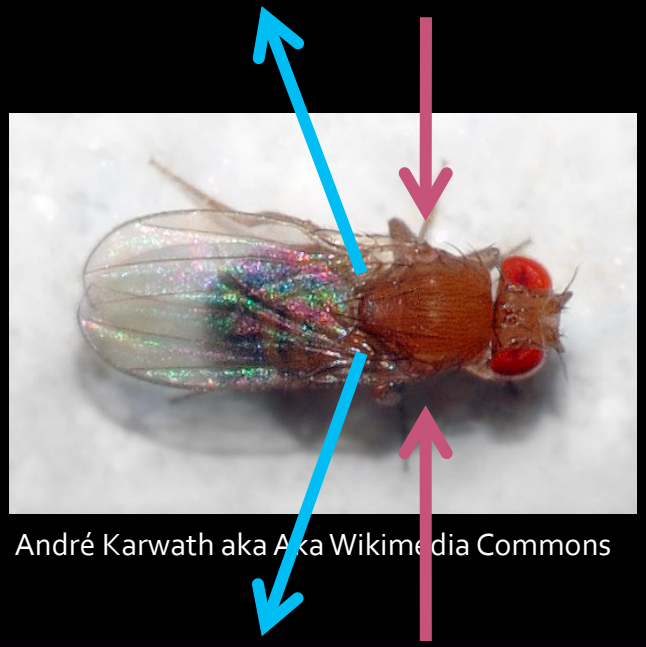
Taking off



Cetonia aurata Ernie Wikimedia Commons

Taking off



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1) In taking off, flies push down their middle legs (the mesothoracic leg)
2) The mesothoracic leg moving down then shifts the thoracic sclerites, resulting in the wings lifting up
3) As the wings lift up, the flight musculature is engaged, resulting in the beginning of flight

A video about flies taking off is below:

http://www.thirteen.org/curious/episodes/inside-the-fly-lab/

Flight and research

- To understand how insects can use stabilization, visual feedback, and various other information to move through their environment, researchers like Mark Frye and Michael Dickinson have worked to characterize how Drosophila can fly and move through the world .
- Look up the movies of flies in experiments:
- Mark Frye:

http://www.physci.ucla.edu/research/frye/movies.htm

Check out the videos at the Dickinson's website to find out how flies fly:

- Michael Dickinson:

http://www.dickinson.caltech.edu/Links

- Researchers have also attempted to use insects and wire them up with electrodes to trigger flight patterns. Check out the video below to learn all about it:
- Cyborg insects:

http://singularityhub.com/2009/03/24/cyborg-insects-take-flight/