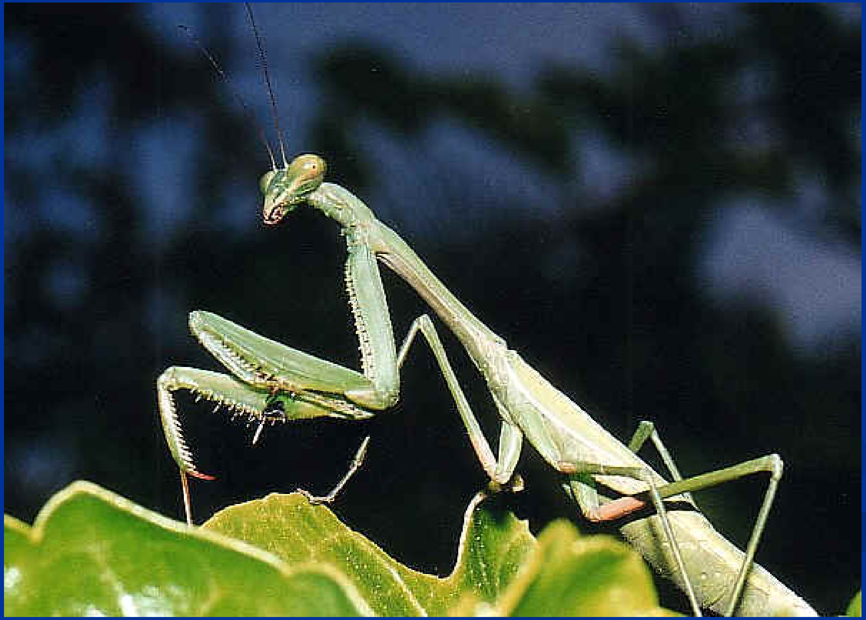
Svaly a pohybový systém

Pohyb – subbuněčný
buněčný
orgánový
organismální – lokomoce

Lokomoce – brvy a bičíky
améboidní
svalová

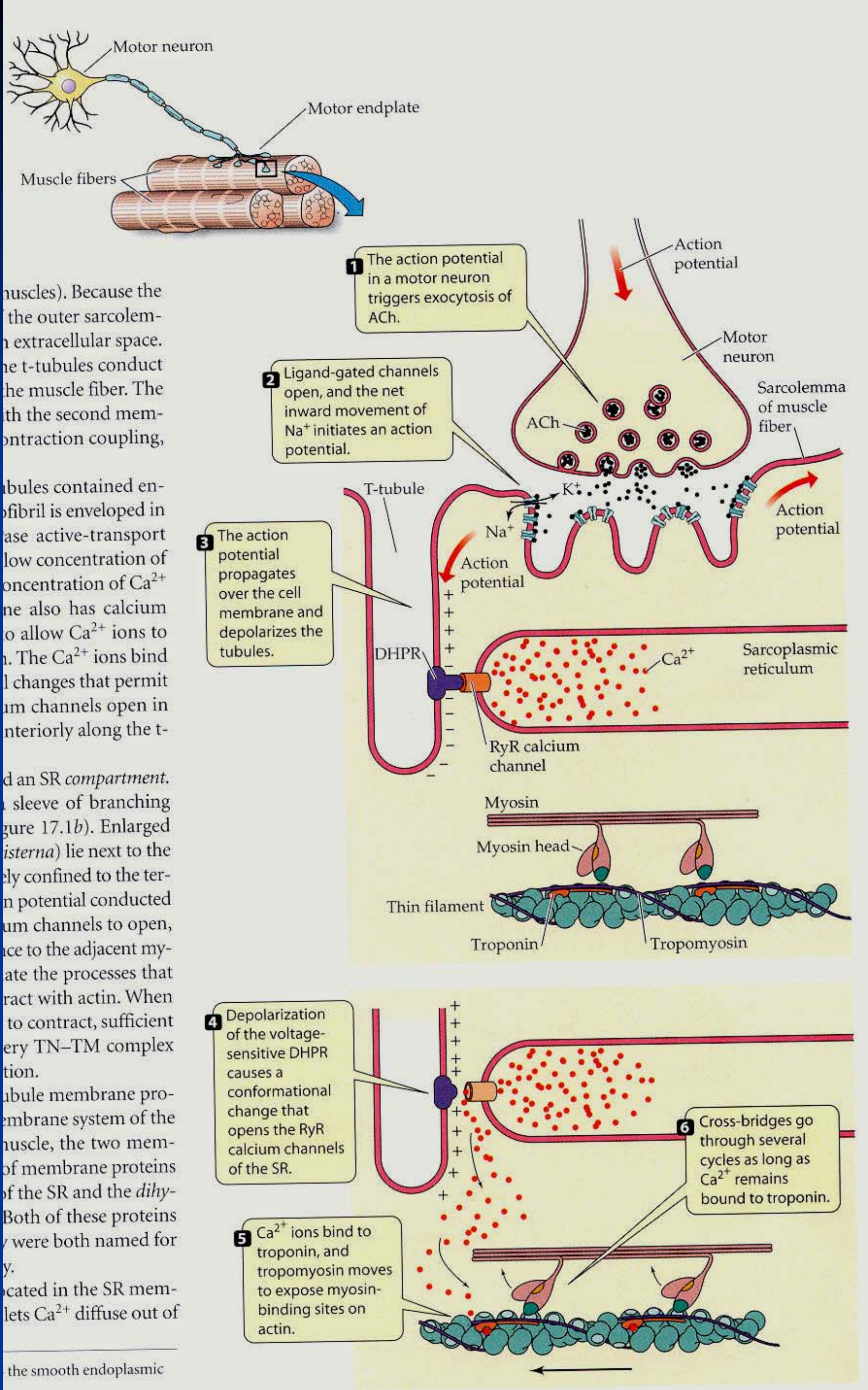
Kostra těla

Hladká a žíhaná svalovina



Univerzální mechanismus stahu

L-glutamová – excitace
GABA - inhibice



uscles). Because the
the outer sarcolem-
extracellular space.
e t-tubules conduct
he muscle fiber. The
th the second mem-
ntraction coupling,

bules contained en-
fibril is enveloped in
ase active-transport
low concentration of
ncentration of Ca^{2+}
ne also has calcium
o allow Ca^{2+} ions to
. The Ca^{2+} ions bind
changes that permit
m channels open in
nteriorly along the t-

d an SR *compartment.*
sleeve of branching
ure 17.1*b*). Enlarged
isterna) lie next to the
ly confined to the ter-
n potential conducted
um channels to open,
ce to the adjacent my-
ate the processes that
ract with actin. When
to contract, sufficient
ery TN–TM complex
tion.
bule membrane pro-
mbrane system of the
uscle, the two mem-
f membrane proteins
f the SR and the *dihy-*
Both of these proteins
were both named for
y.
cated in the SR mem-
lets Ca^{2+} diffuse out of

---

the smooth endoplasmic

1 The action potential in a motor neuron triggers exocytosis of ACh.

2 Ligand-gated channels open, and the net inward movement of Na^+ initiates an action potential.

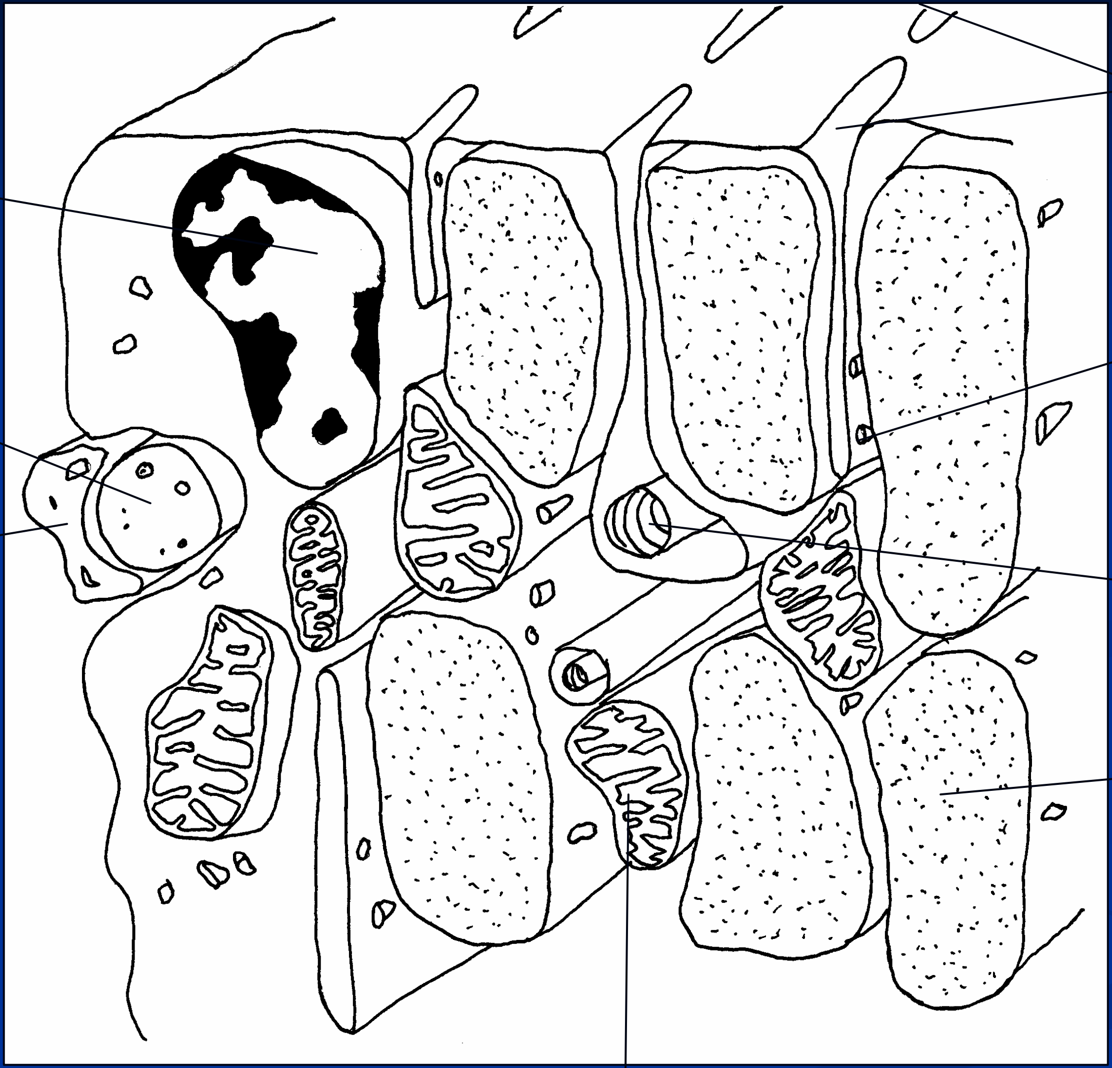
3 The action potential propagates over the cell membrane and depolarizes the tubules.

4 Depolarization of the voltage-sensitive DHPR causes a conformational change that opens the RyR calcium channels of the SR.

5 Ca^{2+} ions bind to troponin, and tropomyosin moves to expose myosin-binding sites on actin.

6 Cross-bridges go through several cycles as long as Ca^{2+} remains bound to troponin.

Sval hmyzu



T-tubuly

Jádro

Sarkoplazmatické retikulum

Axon

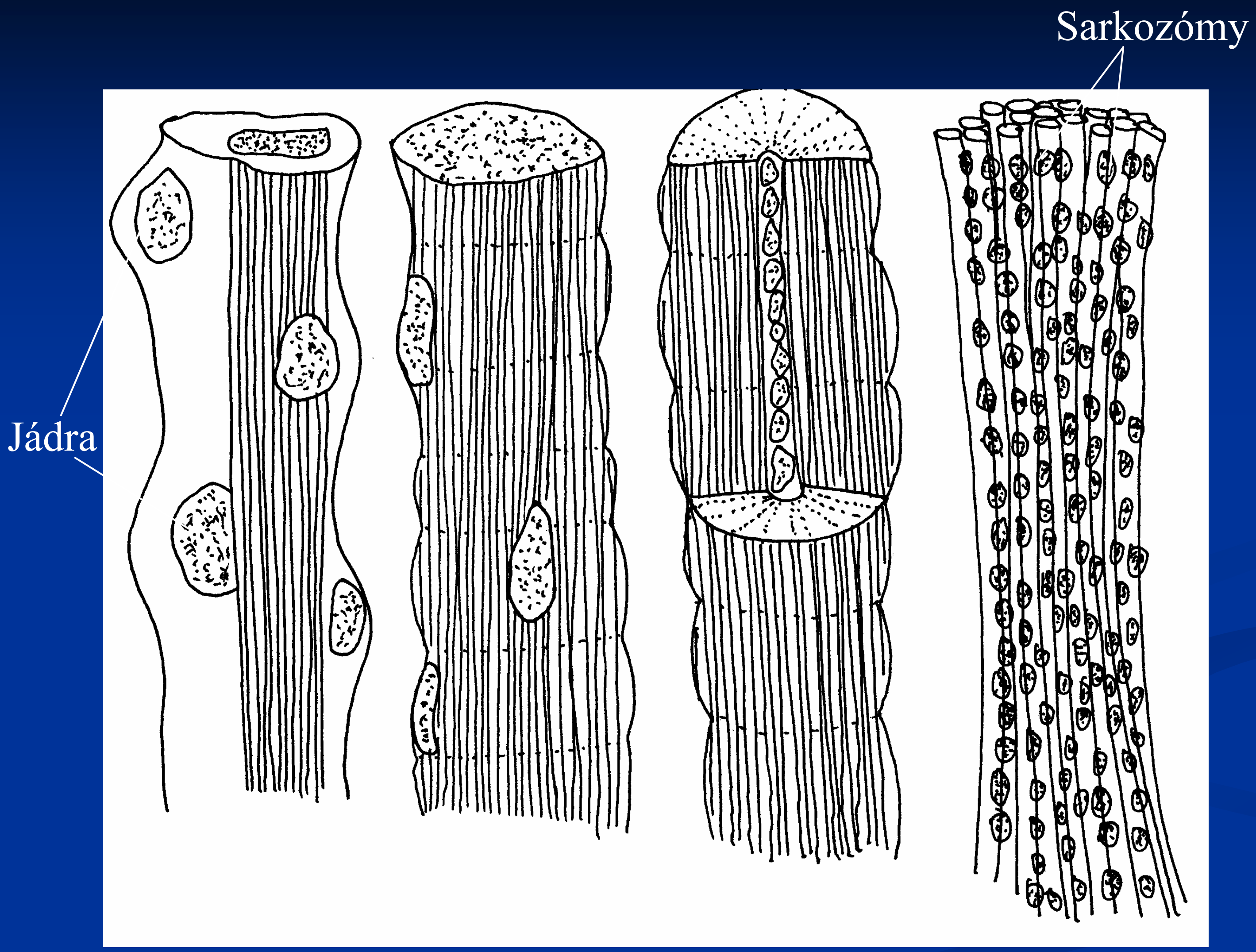
Gliová b.

Tracheola

Fibrila

Mitochondrie

Svaly hmyzu

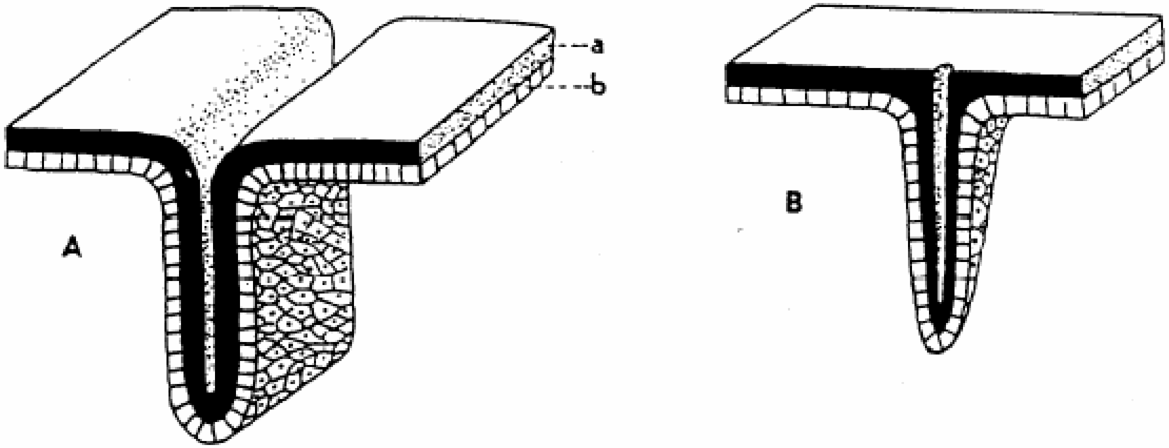


Osové Disperzní Trubicovité Fibrilární (asynchronní)

Exoskelet hmyzu
Flexory a extenzory

Schéma exoskeletu hmyzu

a = tergum, b = intersegmentální membrána, c = sternum, d = končetinový článek, e = hlavová schránka



Endoskeletní útvary hmyzu

A - endoskeletní lišta, B - apodema; a = kutikula, b = epidermis

Tonofibrily

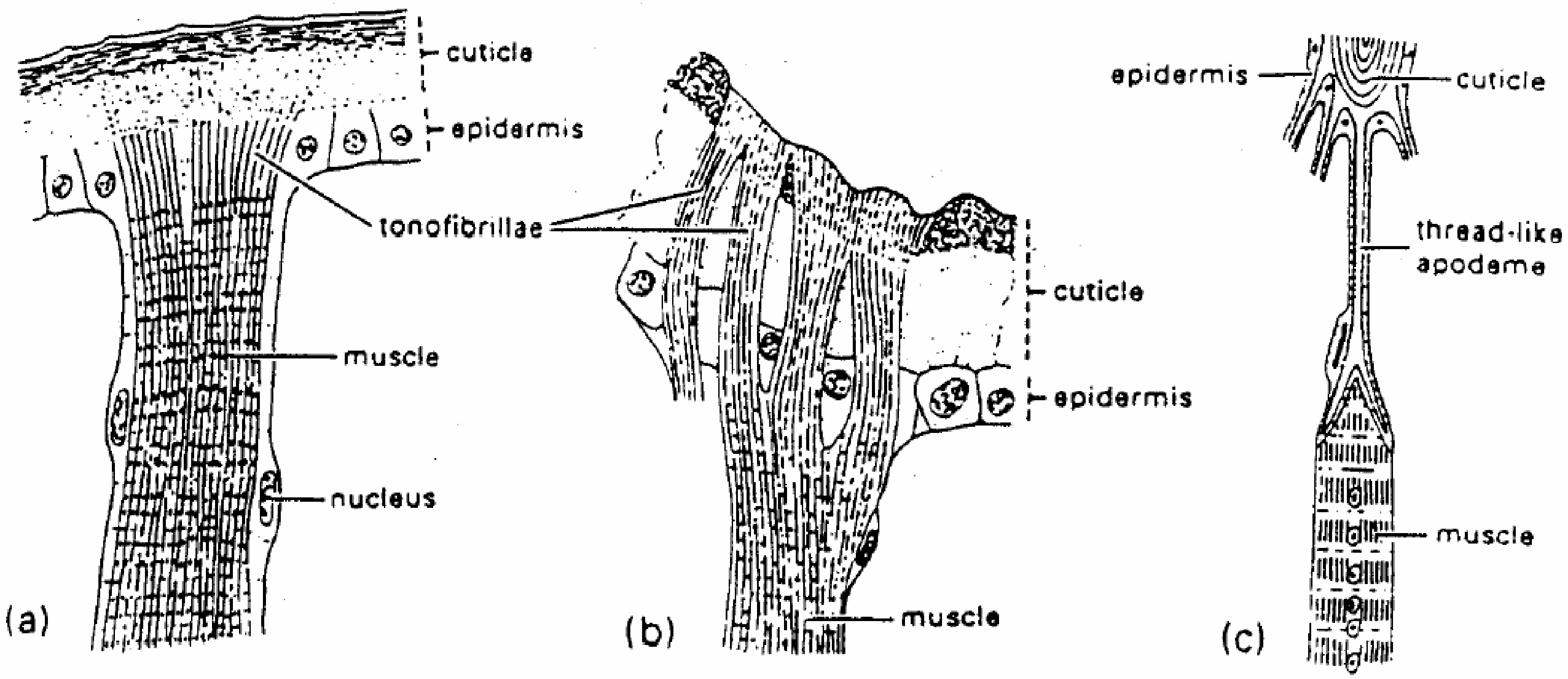
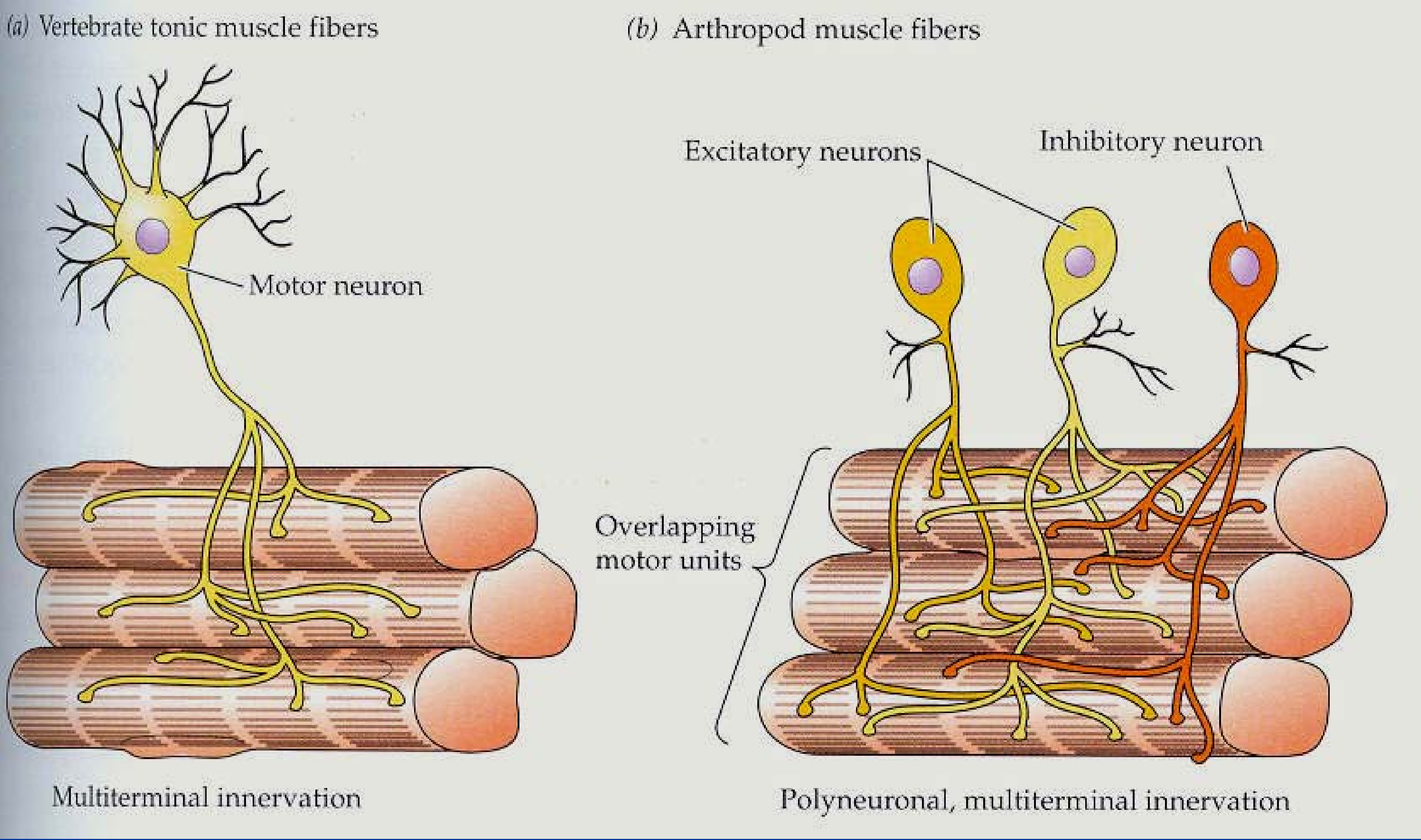


Fig. 3.2 Muscle attachments to body wall: (a) tonofibrillae traversing the epidermis from the muscle to the cuticle; (b) a muscle attachment in an adult beetle of *Chrysobothrus femorata* (Coleoptera: Buprestidae). (c) a multicellular apodeme with a muscle attached to one of its thread-like, cuticular 'tendons'. (After Snodgrass, 1935.)

Inervace -3 typy neuronů bezobratlých
L-glutamová – excitace
GABA - inhibice



„Větší“ síla malého svalu

Pomalé a rychlé svaly

6:1 actin:myosin

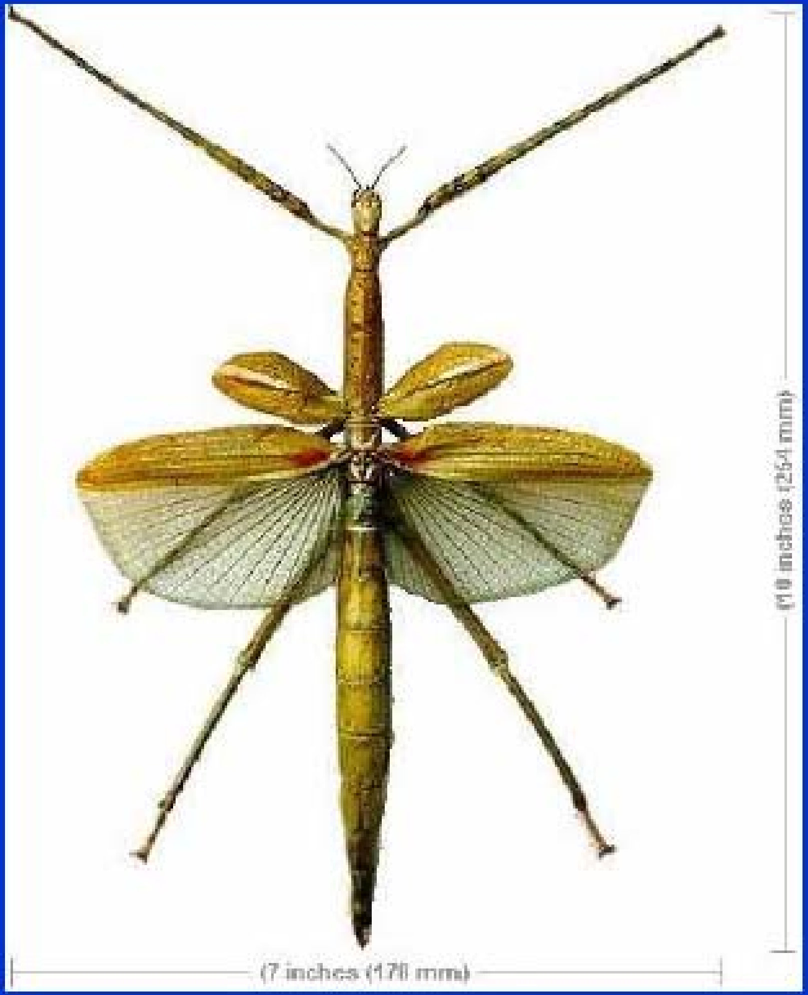
3:1 actin:myosin

FIGURE 10.8 Cross sections of slow (left) and fast (right) muscle fibers. From Aidley (1985). Reprinted with permission.

Stání, chůze, lezení, let

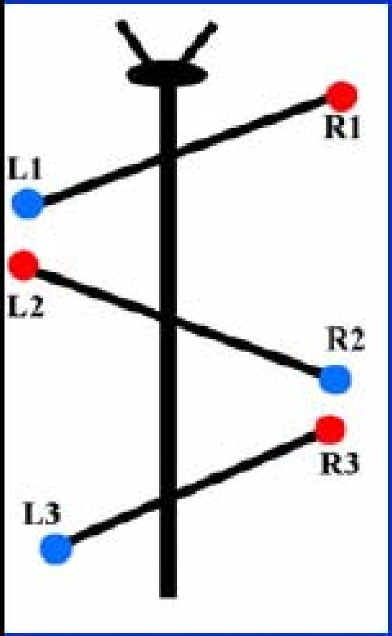
Walking

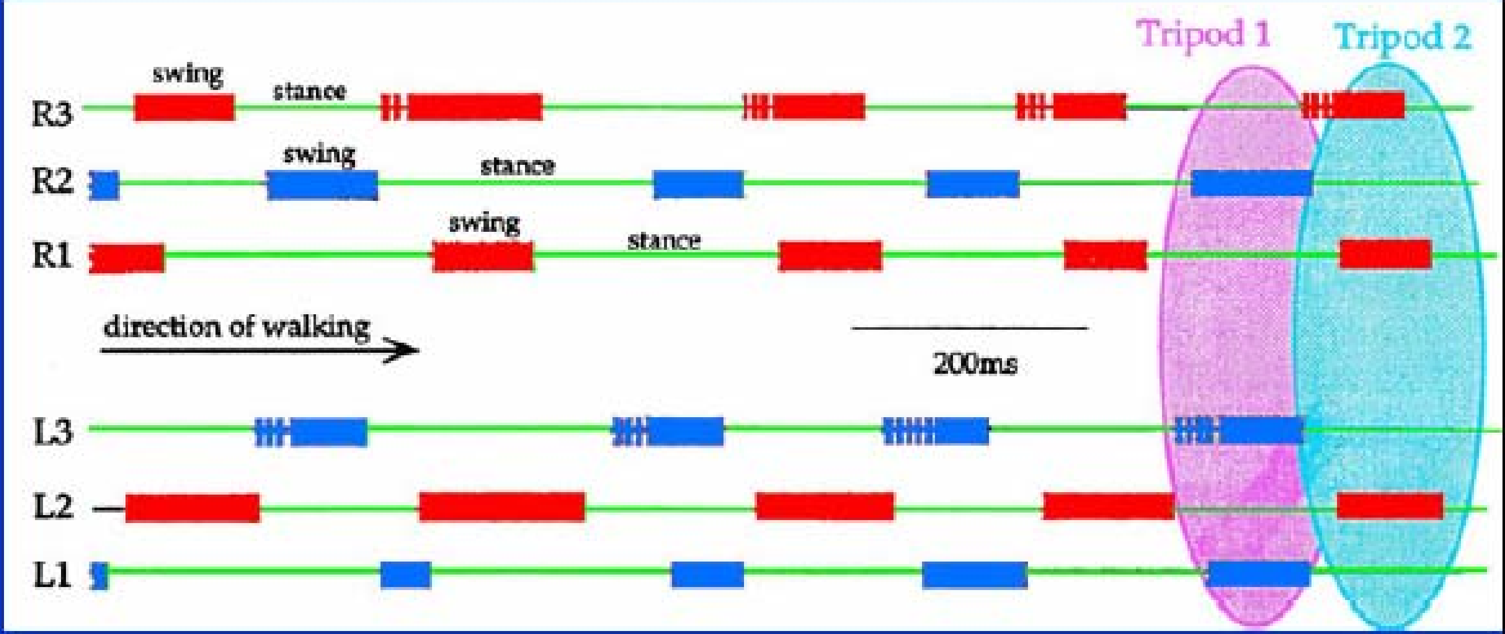
Central Pattern Generation



Gaits in insect walking:

tripod gait

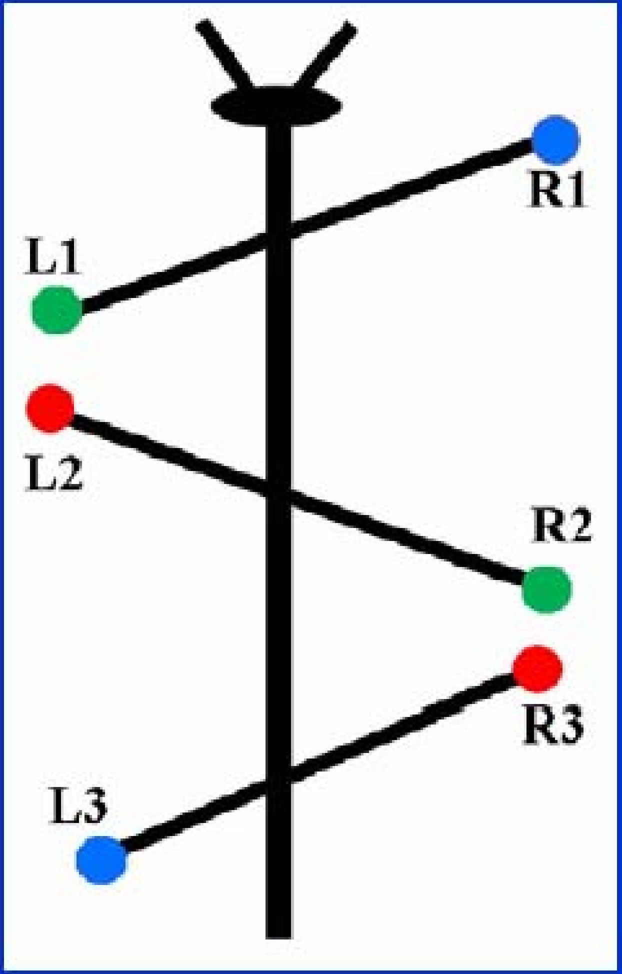




cockroach (*Periplaneta americana*)

0.44-1m/s alternating tripod gait

1-1.5 m/s quadruped gait or bipedal



adult stick insects use tetrapod gait

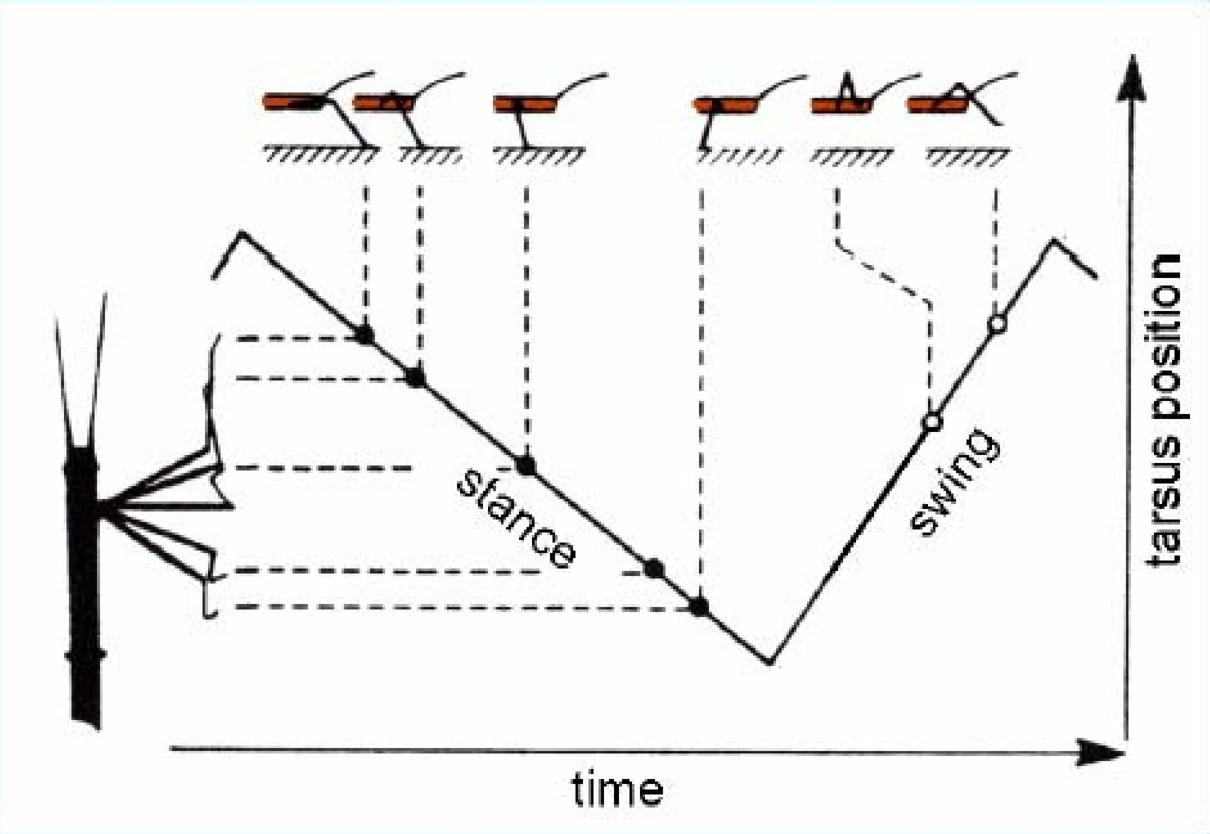
(like “walk”, tripod gait like “trot”)

Walking: cycle of movements

stance phase:

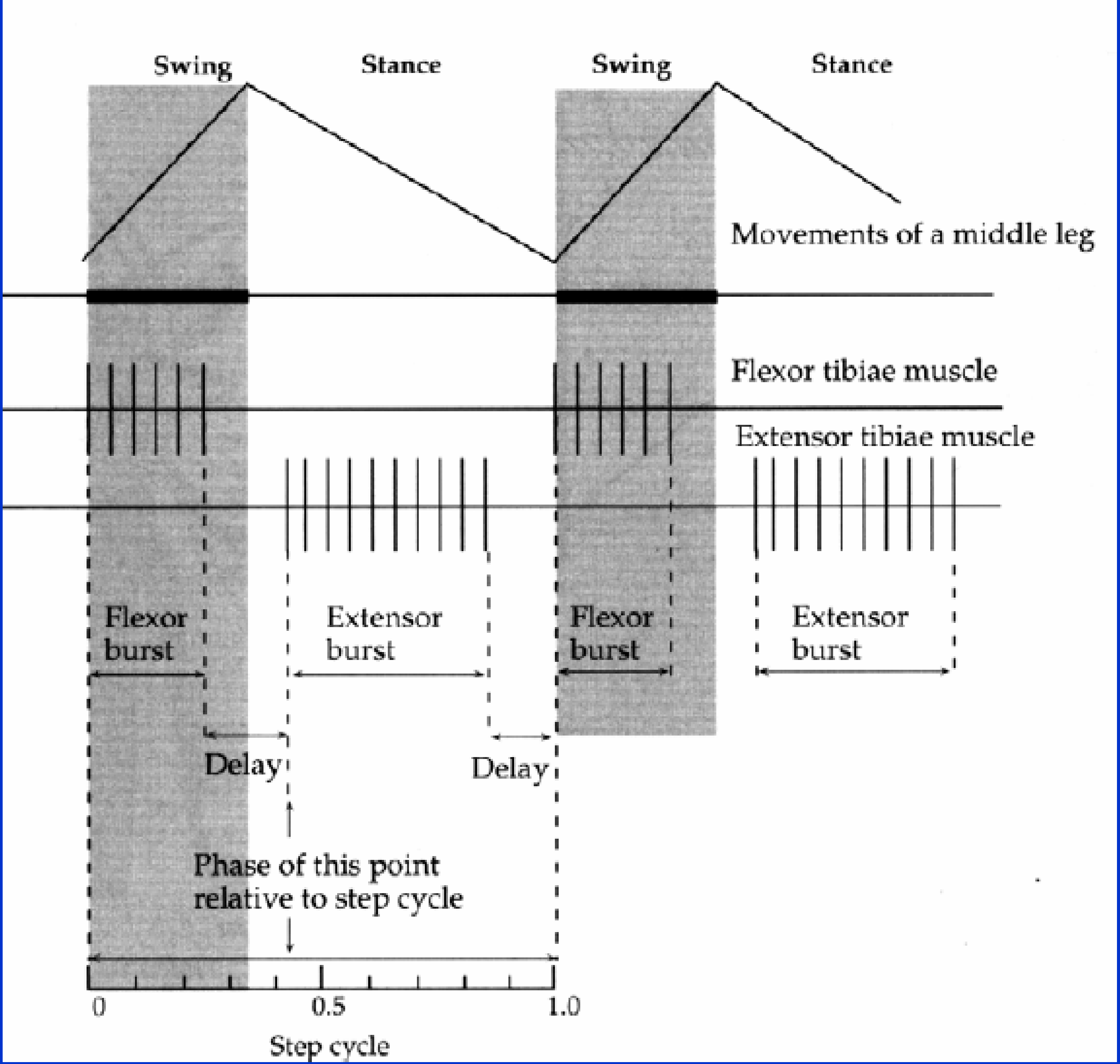
-tarsi in contact with the ground
-backward movement of legs
-extensor motoneurons and muscles active

-> body moves forward



swing phase

-tarsi not in contact with ground
-forward movement of legs
-flexor motoneurons and muscles active


Swing
Stance
Swing
Stance
Movements of a middle leg
Flexor tibiae muscle
Extensor tibiae muscle
Flexor burst
Extensor burst
Flexor burst
Extensor burst
Delay
Delay
Phase of this point relative to step cycle
0
0.5
1.0
Step cycle

Pattern generators in walking

alternative hypotheses:

one central pattern generator for all legs?

one central pattern generator for each leg?

Generátory pohybu

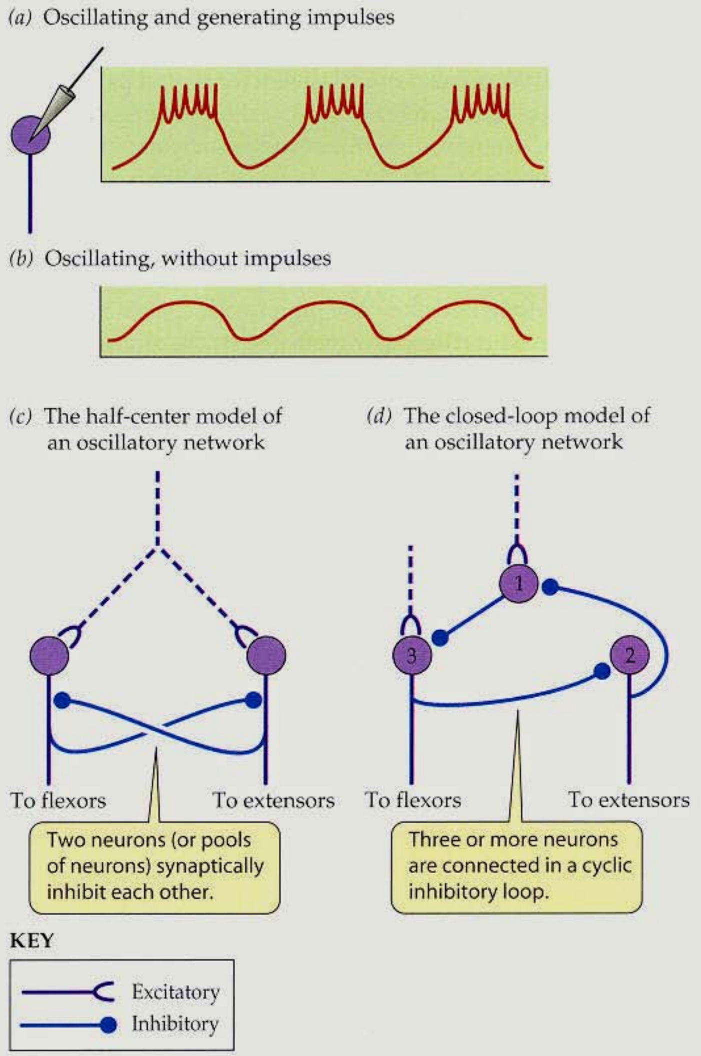
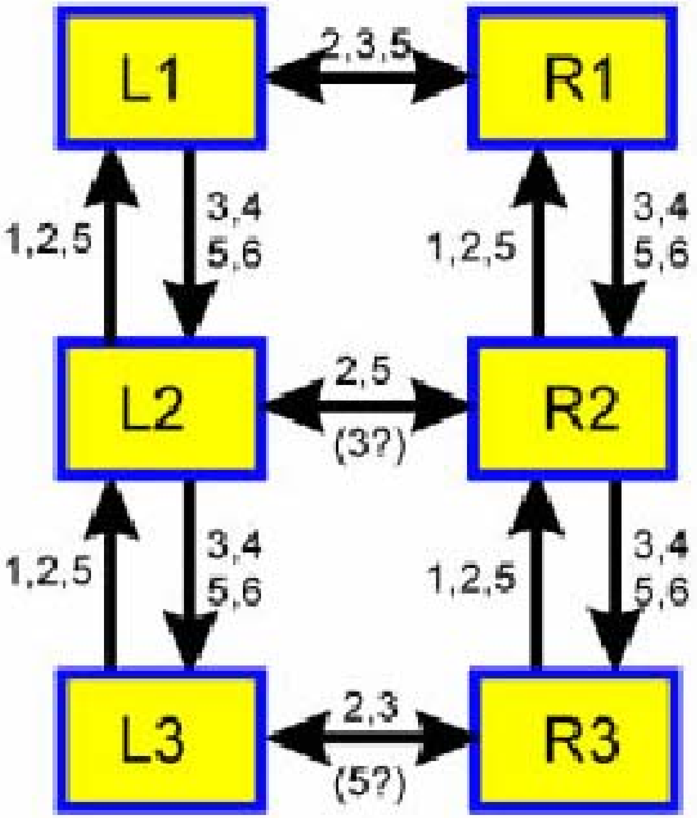


Figure 18.9 Models of oscillators underlying central pattern generators *(a)* An oscillator neuron generating bursts of impulses (e.g., in *Aplysia*). *(b)* A neuron with membrane-potential oscillation but without impulses (e.g., a neuron controlling pumping of the crustacean scaphognathite, or gill bailer). *(c)* A network oscillator composed of reciprocal inhibitory half-centers. *(d)* A network oscillator composed of closed-loop cyclic inhibition. All three cells may be spontaneously active or may receive unpatterned excitatory input (dashed lines). If cell 1 is active first, its activity inhibits cell 3, but this inhibition prevents cell 3 from inhibiting cell 2. Cell 2 can now be active, inhibiting cell 1 and thus releasing cell 3 from inhibition. Cell 3 can then be active, inhibiting cell 2 and releasing cell 1 from inhibition, and so forth.

Coordination between legs in the stick insect



1. swing phase inhibits swing (anterior)
2. start of stance excites start of swing (anterior, lateral)
3. caudal positions excite start of swing (posterior, lateral)
4. targeting (tarsi go to last position of anterior tarsi, lateral)

5a. increased resistance increases force (coactivation; all directions)

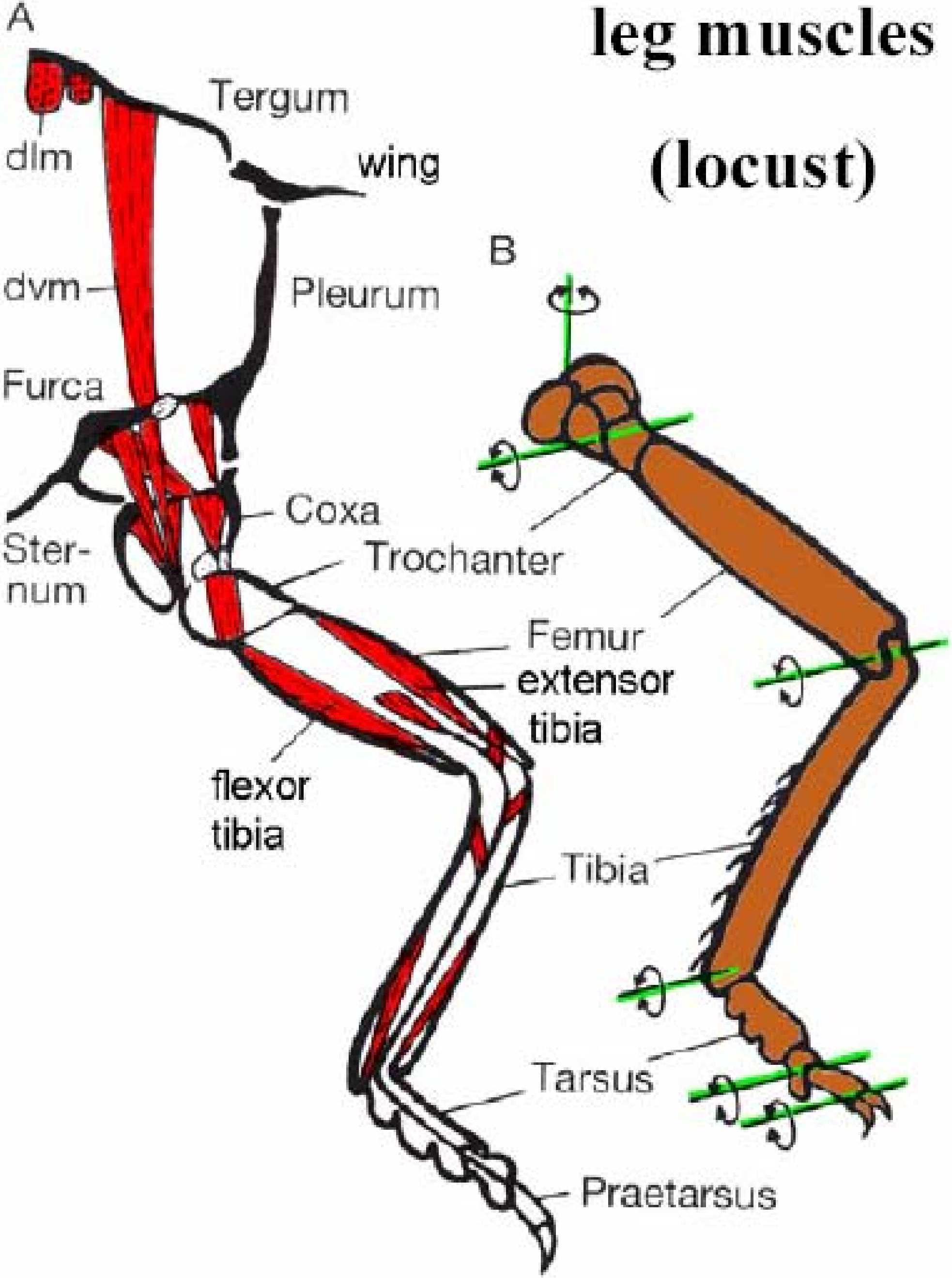
5b. increased load prolongs stance (all directions)

6. do not step on your own toes

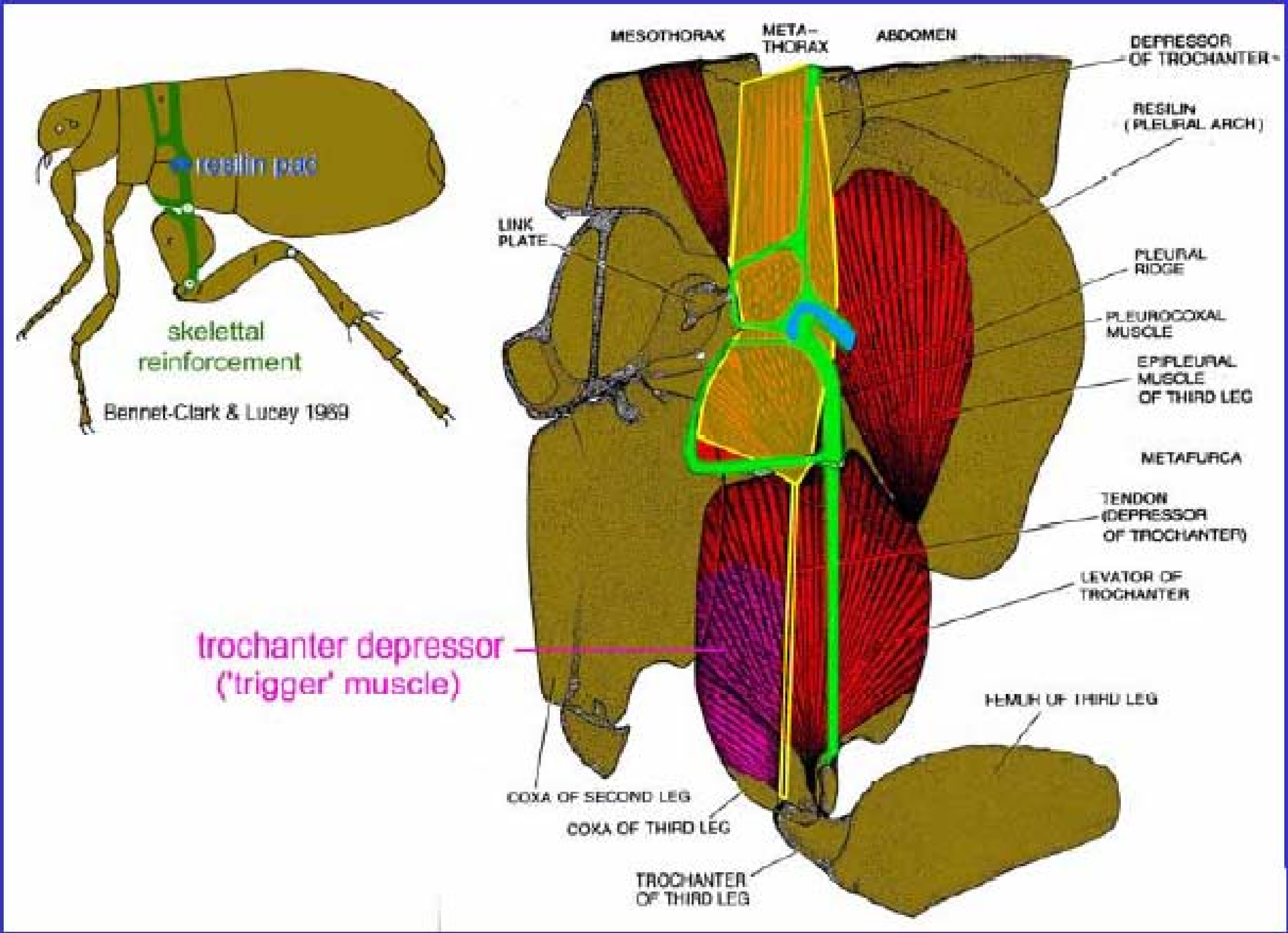
"The temporal sequence of the movements of all legs can be explained by the actions of a distributed command structure consisting of six more or less independent walking-pattern generators and at least three different kinds of coordinating pathways between them. " (Bassler, Buschges 1998)

leg muscles

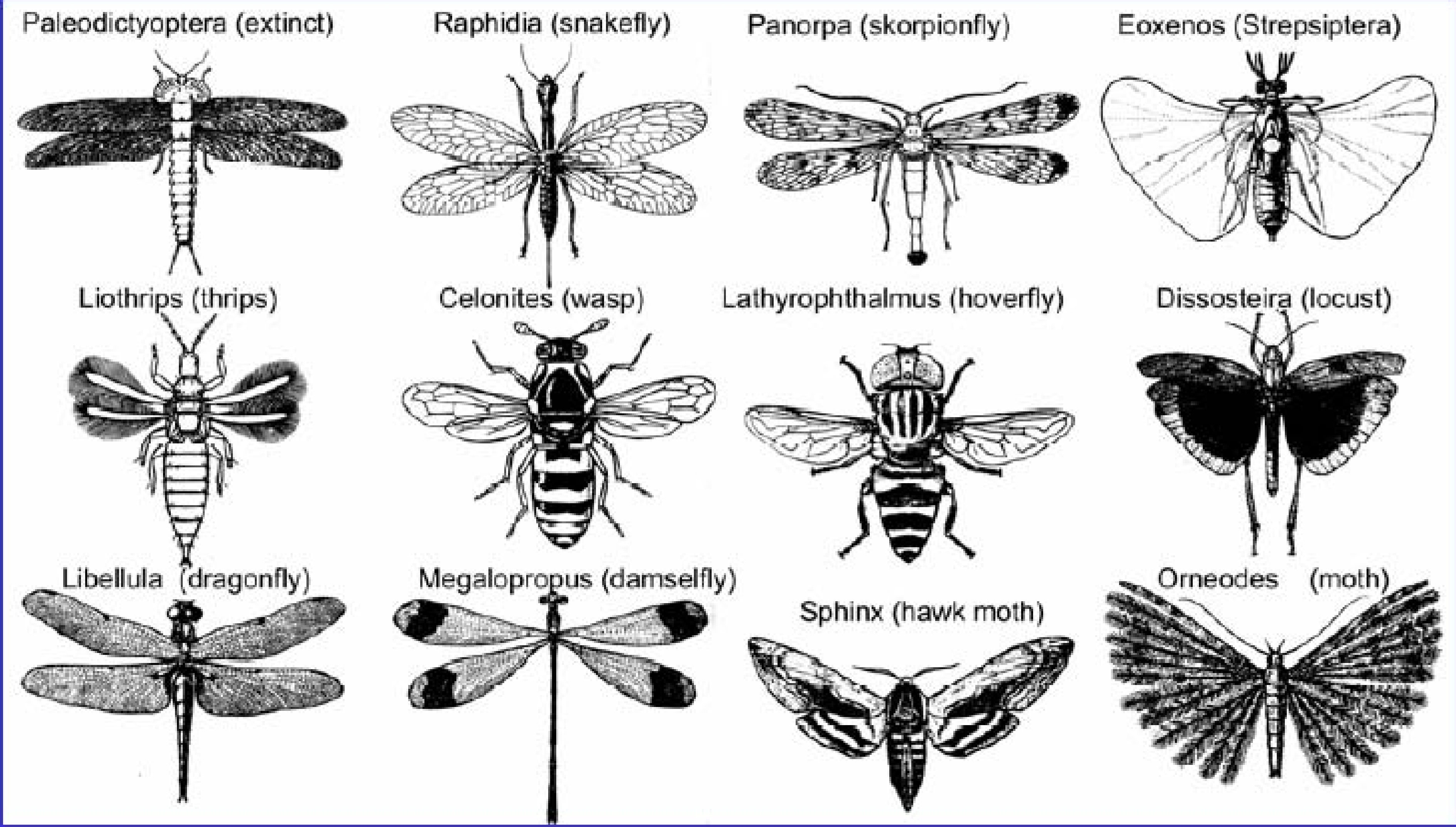
(locust)



Muscles contract before the jump. Energy is stored elastically



Most pterygote insects have 4 wings. Wings can have different shapes.



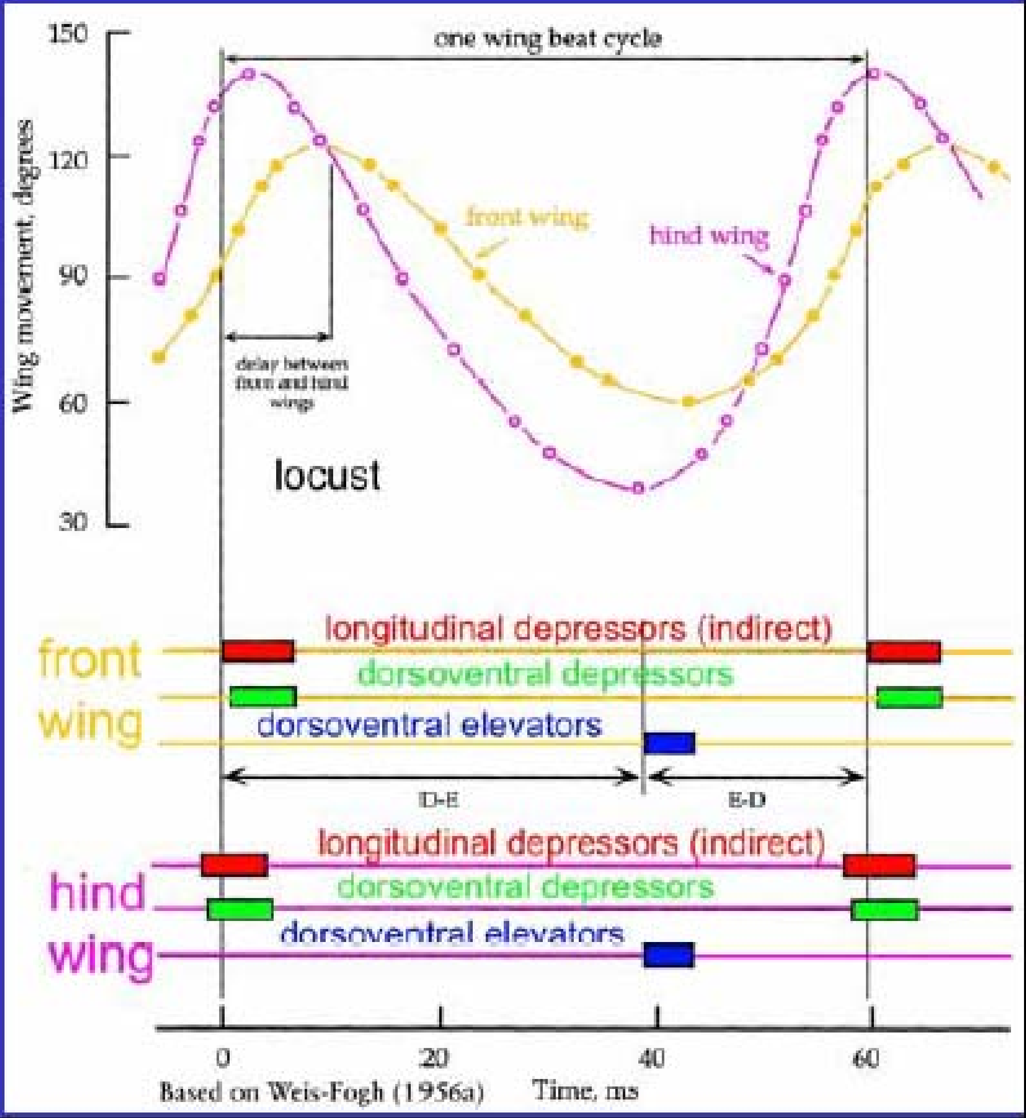
In basal insect taxa, fore and hind wings are similar

scorpionfly

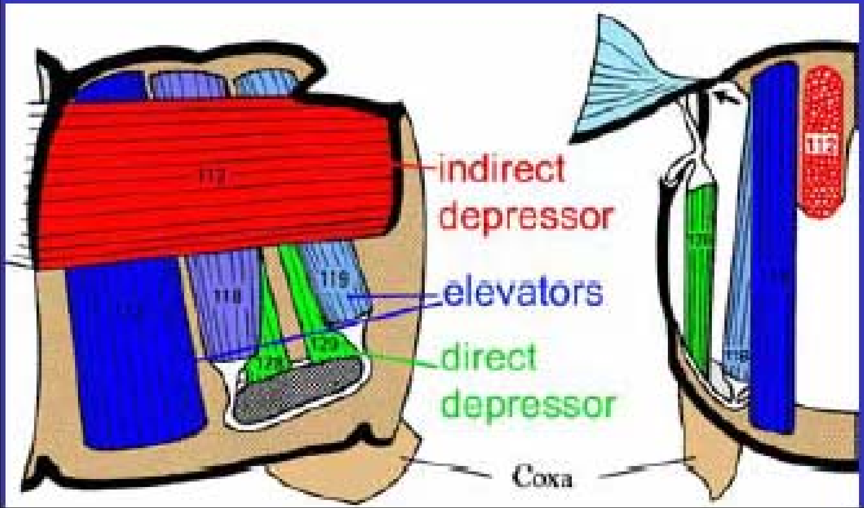
Libellula

The evolutionary trend is towards different fore and hind wings and towards functional two-winged-ness

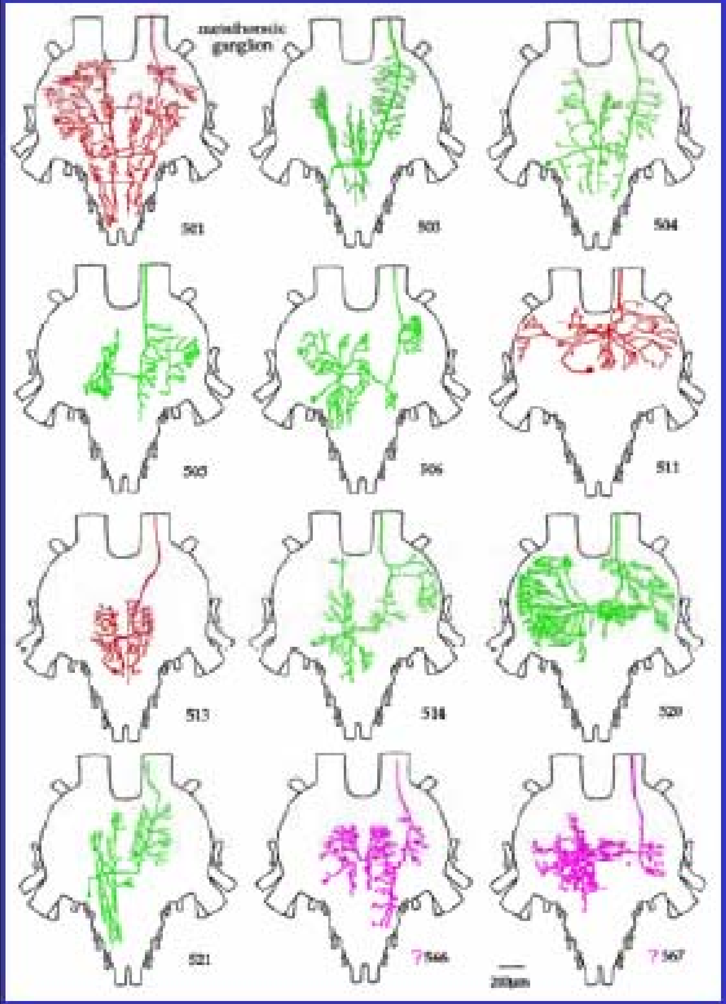
Fore wings and hind wings may be phase-shifted and may differ in stroke amplitude

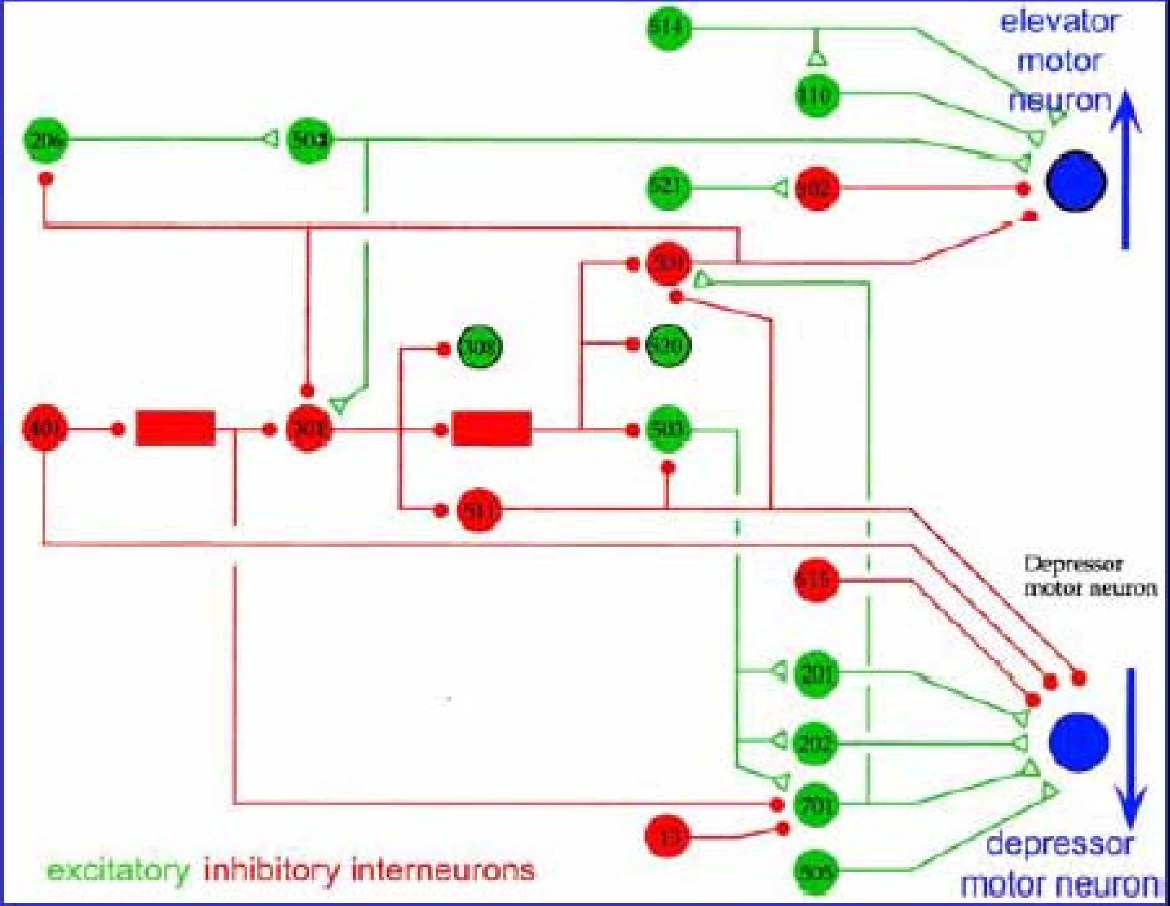


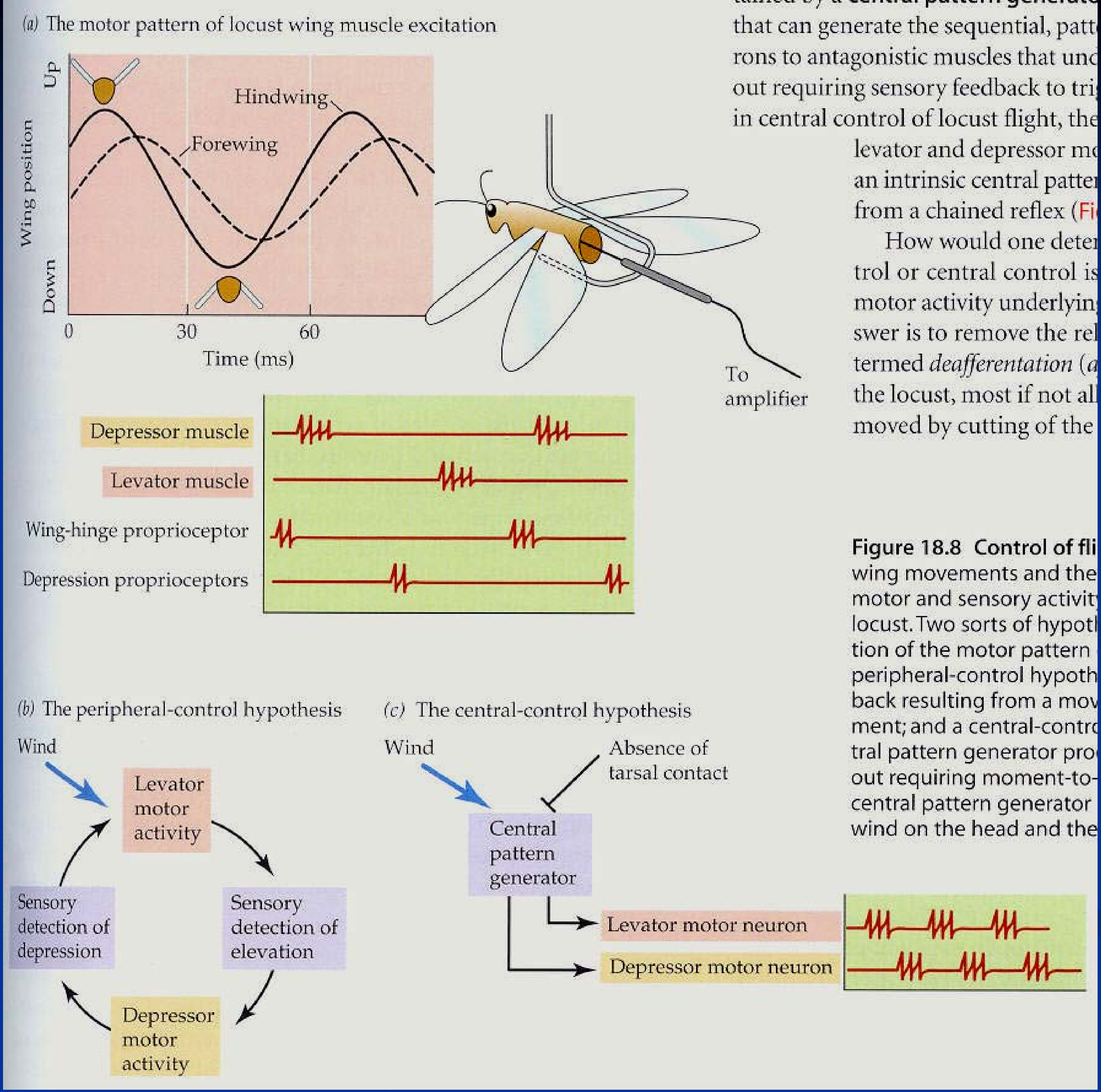
Based on Weis-Fogh (1956a)



The flight oscillator comprises feedback loops and many inhibitory interneurons







that can generate the sequential, patt
rons to antagonistic muscles that unc
out requiring sensory feedback to tri
in central control of locust flight, the
levator and depressor m
an intrinsic central patte
from a chained reflex (Fi
How would one dete
trol or central control is
motor activity underlyin
swer is to remove the re
termed *deafferentation* (a
the locust, most if not al
moved by cutting of the

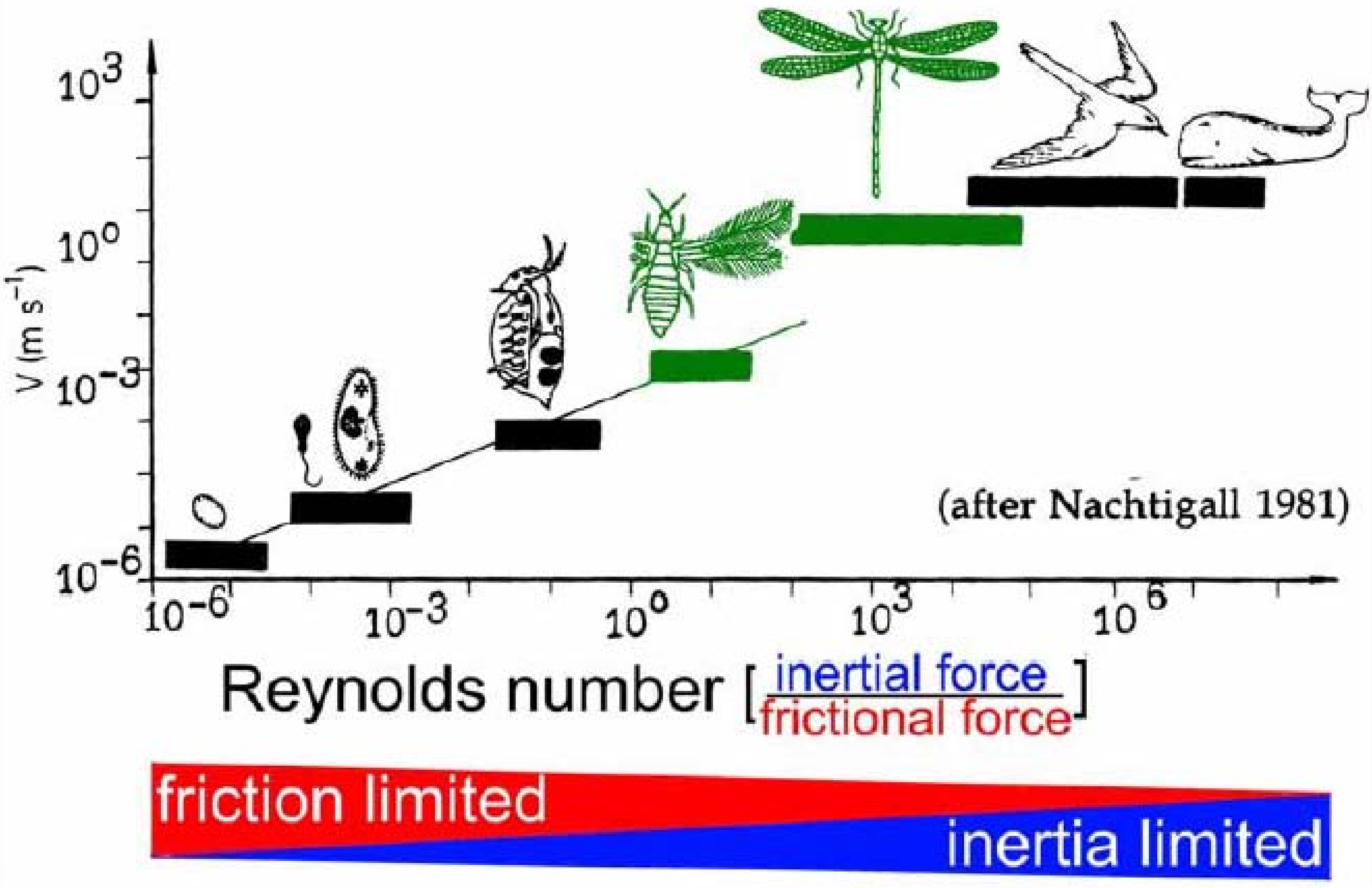
(*a*) The motor pattern of locust wing muscle excitation

(*b*) The peripheral-control hypothesis

(*c*) The central-control hypothesis

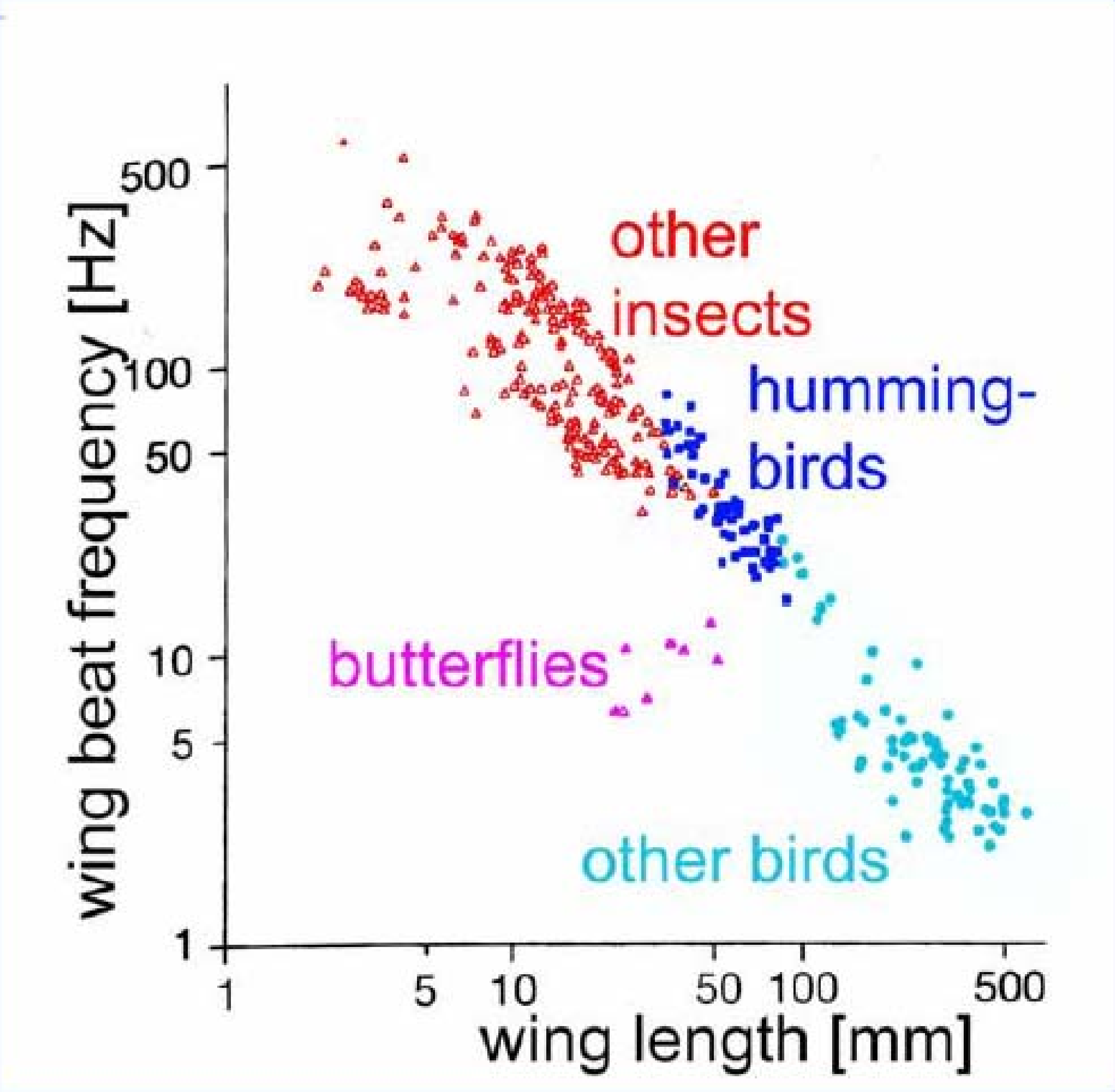
Figure 18.8 Control of fli
wing movements and the
motor and sensory activit
locust. Two sorts of hypot
tion of the motor pattern
peripheral-control hypoth
back resulting from a mov
ment; and a central-contr
tral pattern generator pro
out requiring moment-to-
central pattern generator
wind on the head and the

Flight requirements are different for large and small insects



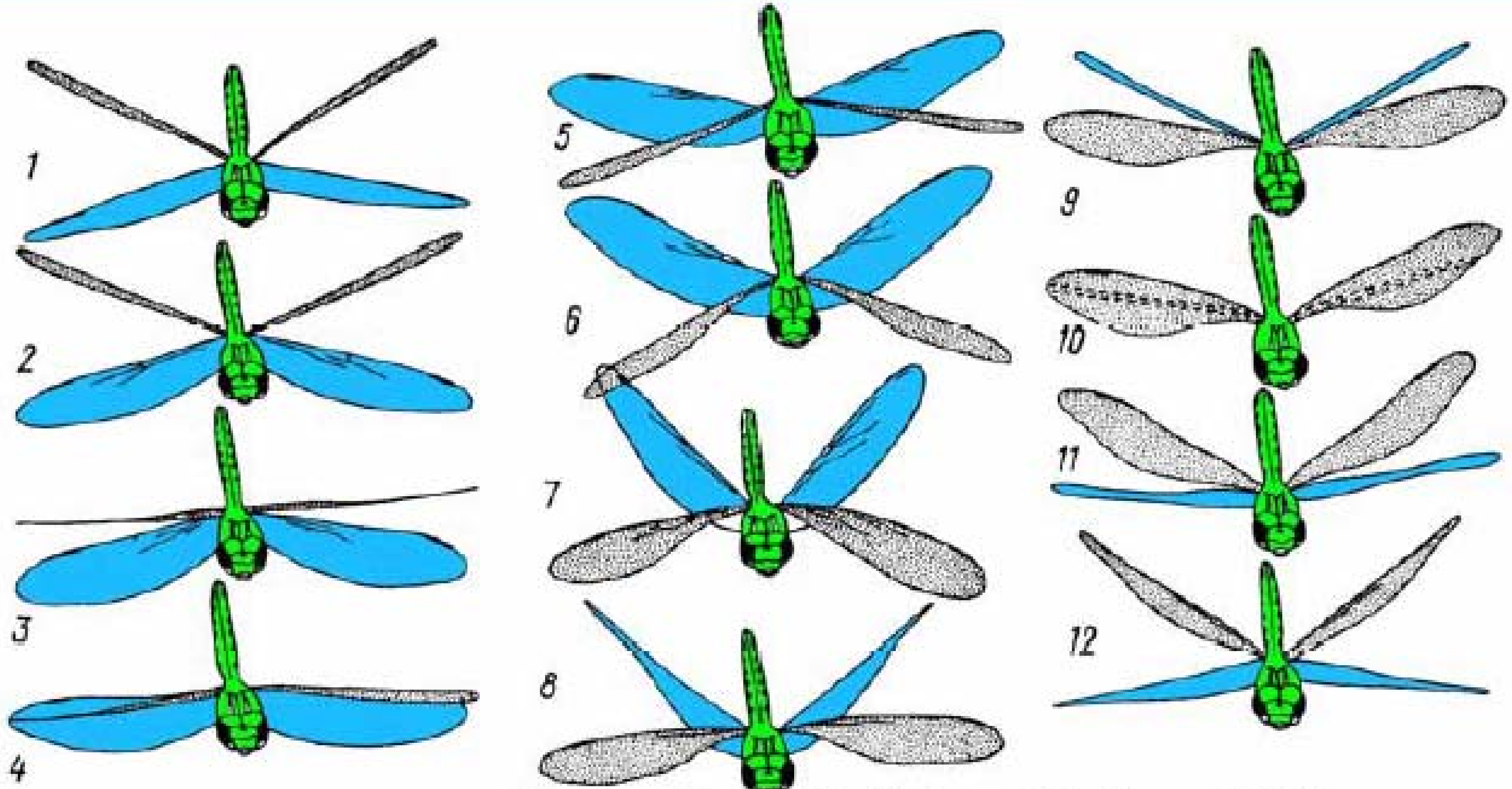
(after Nachtigall 1981)

Small animals beat their wings at higher frequencies



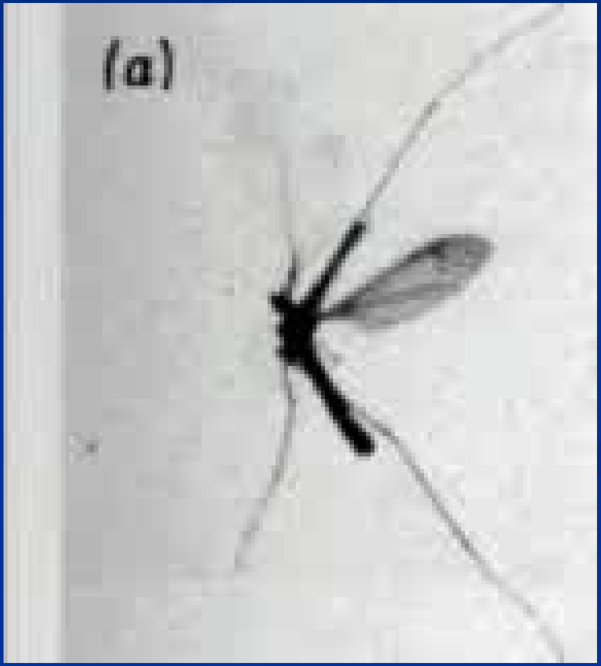
Some insects can hover. Dragonflies beat fore wings and hind wings in anti-phase.

Other insects change the angles of wings and body axis and produce lift without thrust.

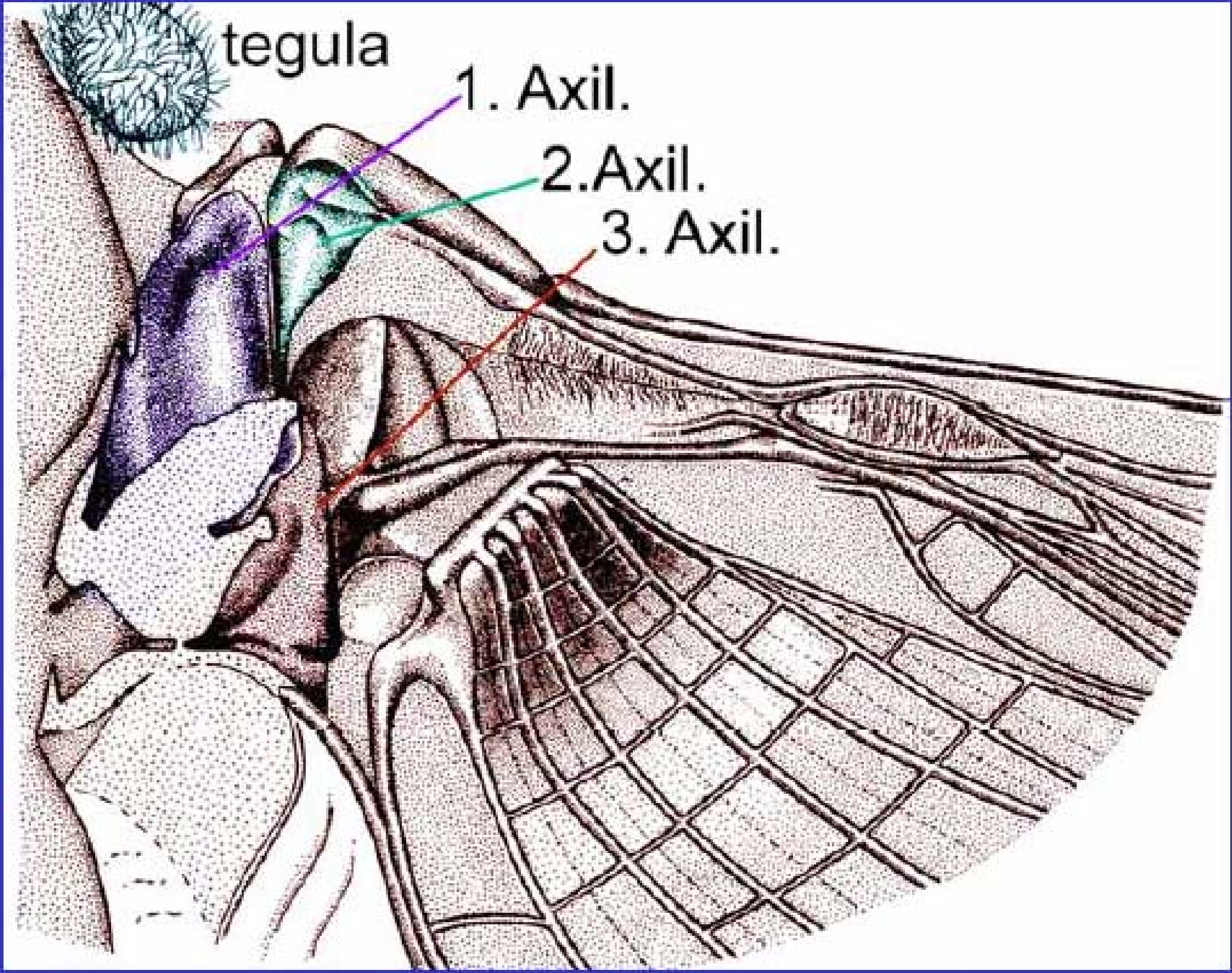


Aeschna junacea hovering flight Norberg 1975

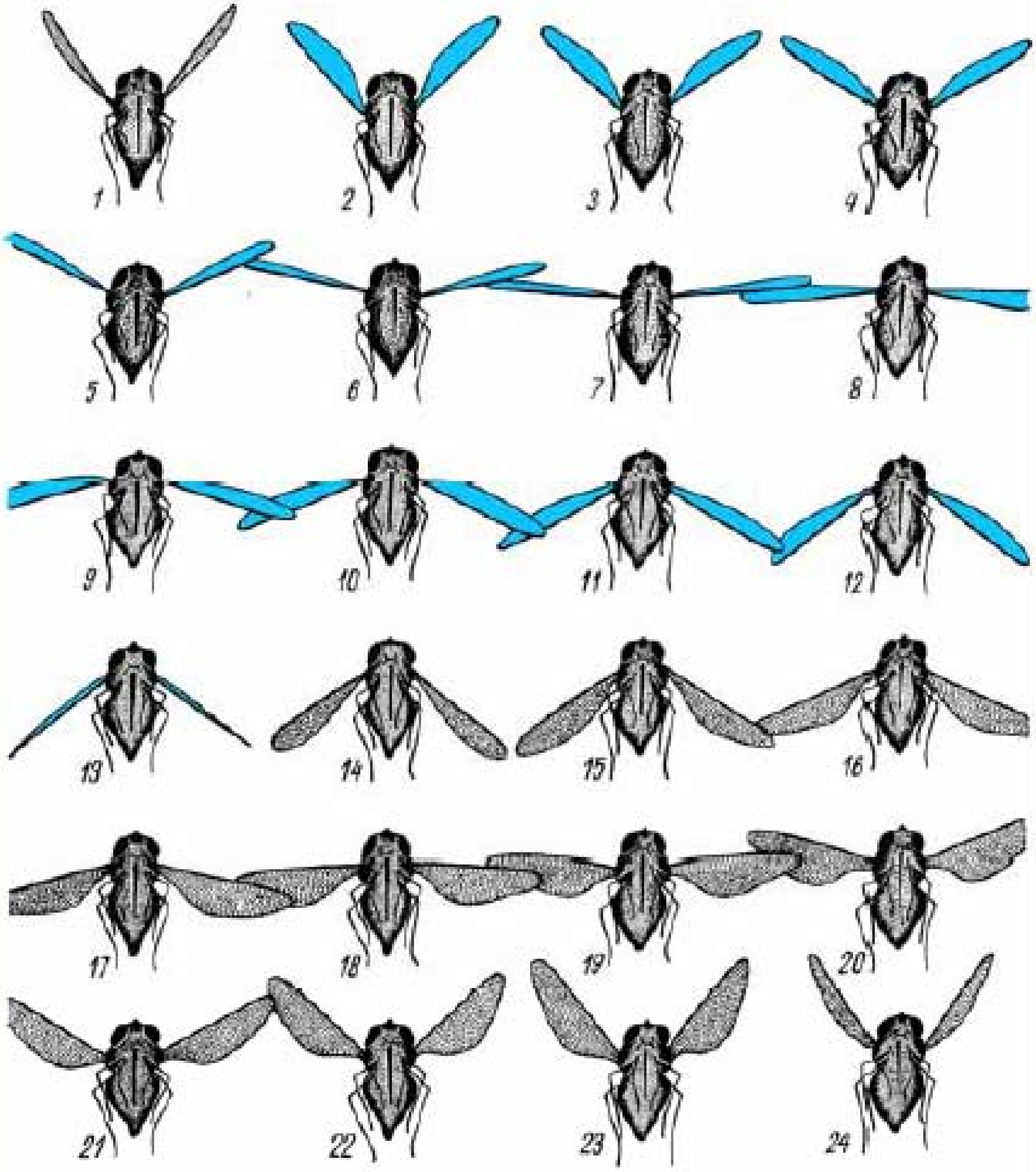
forewings shaded; wing beat frequency 17 Hz


(a)

Muscles attach to the wing base and control wing beat, rotation and torsion



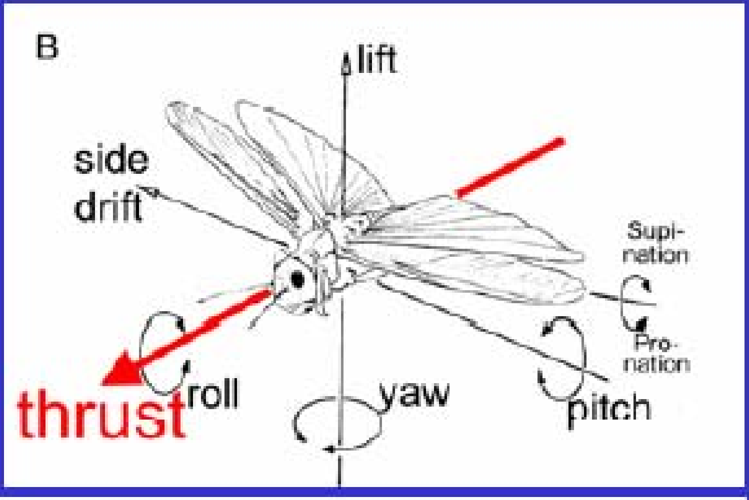
during the upstroke the wing is rotated ventral side up

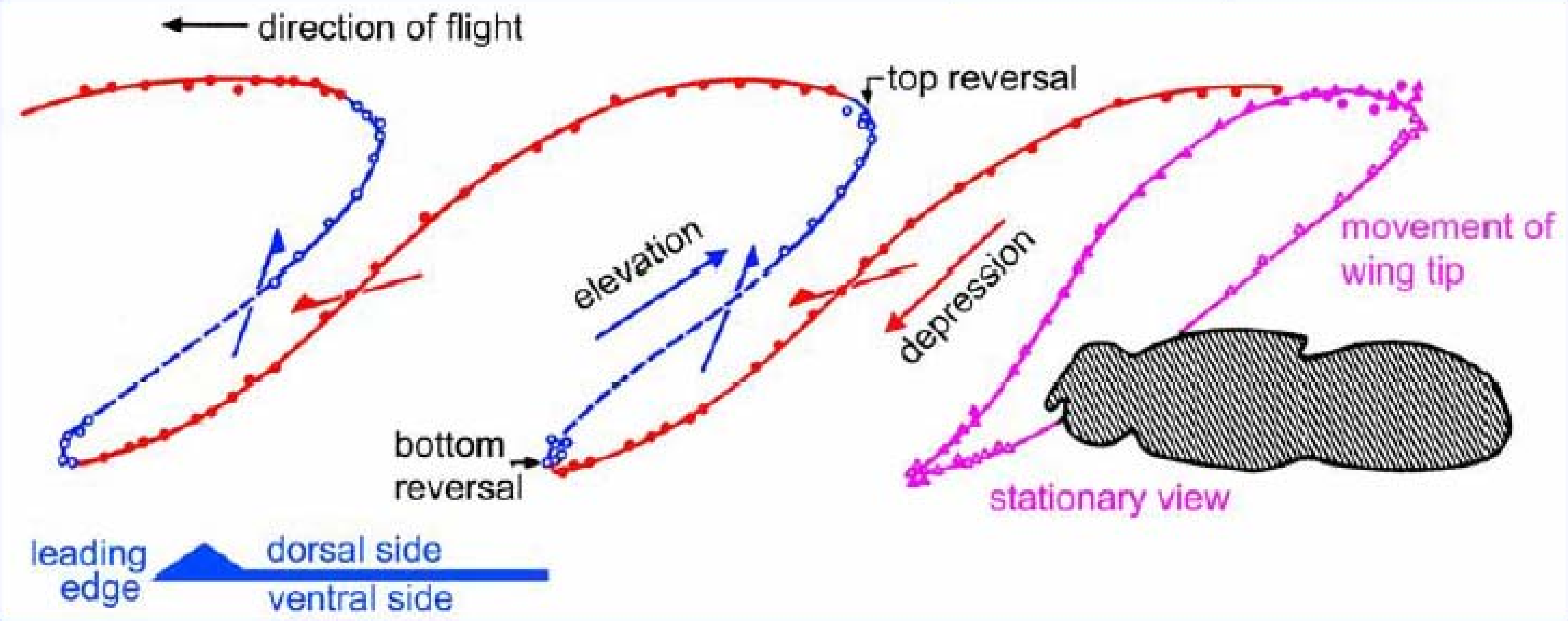


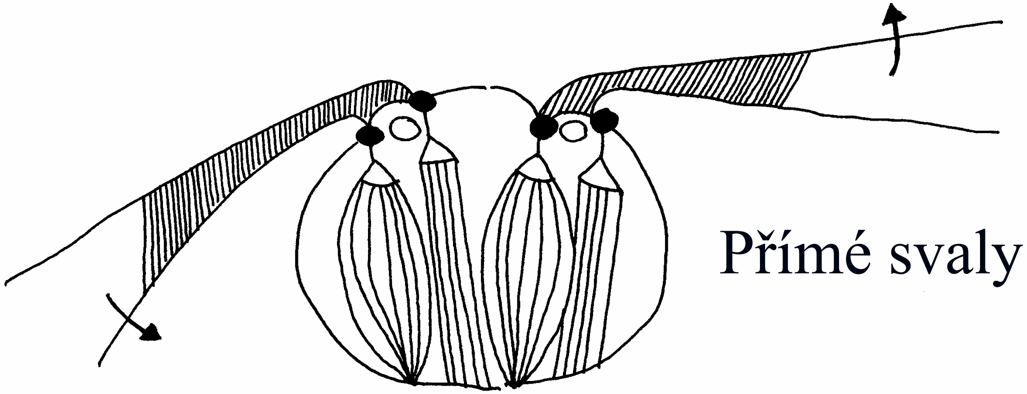
10 mm *Nemestrino capito* A. Brodsky 1994

undersurface shaded; wing beat frequency 143 Hz

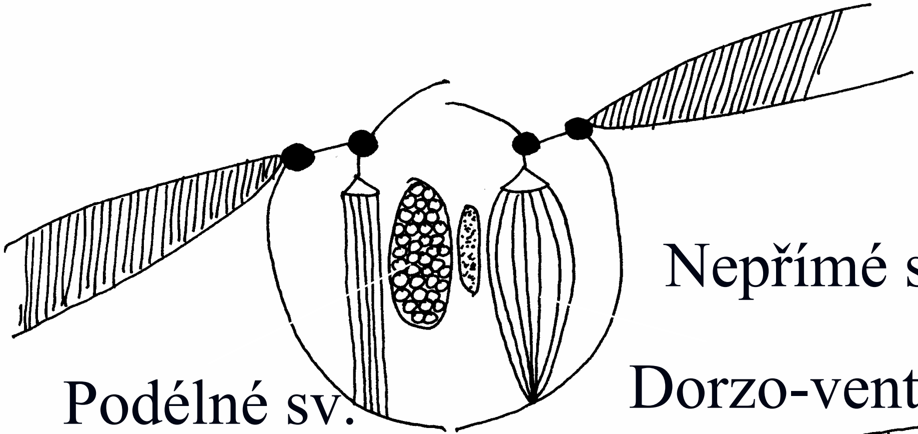
Wing rotation increases thrust







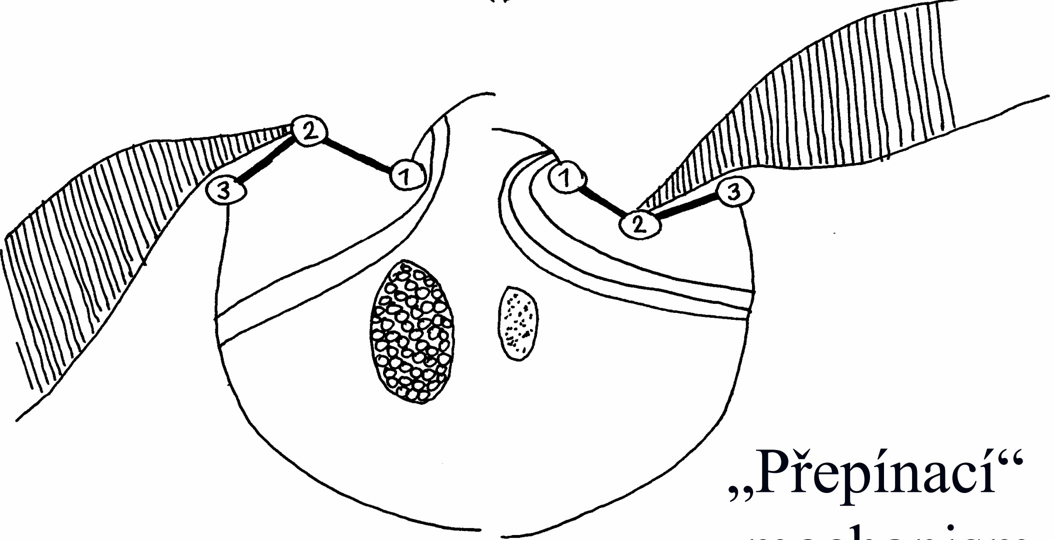
Přímé svaly



Nepřímé svaly

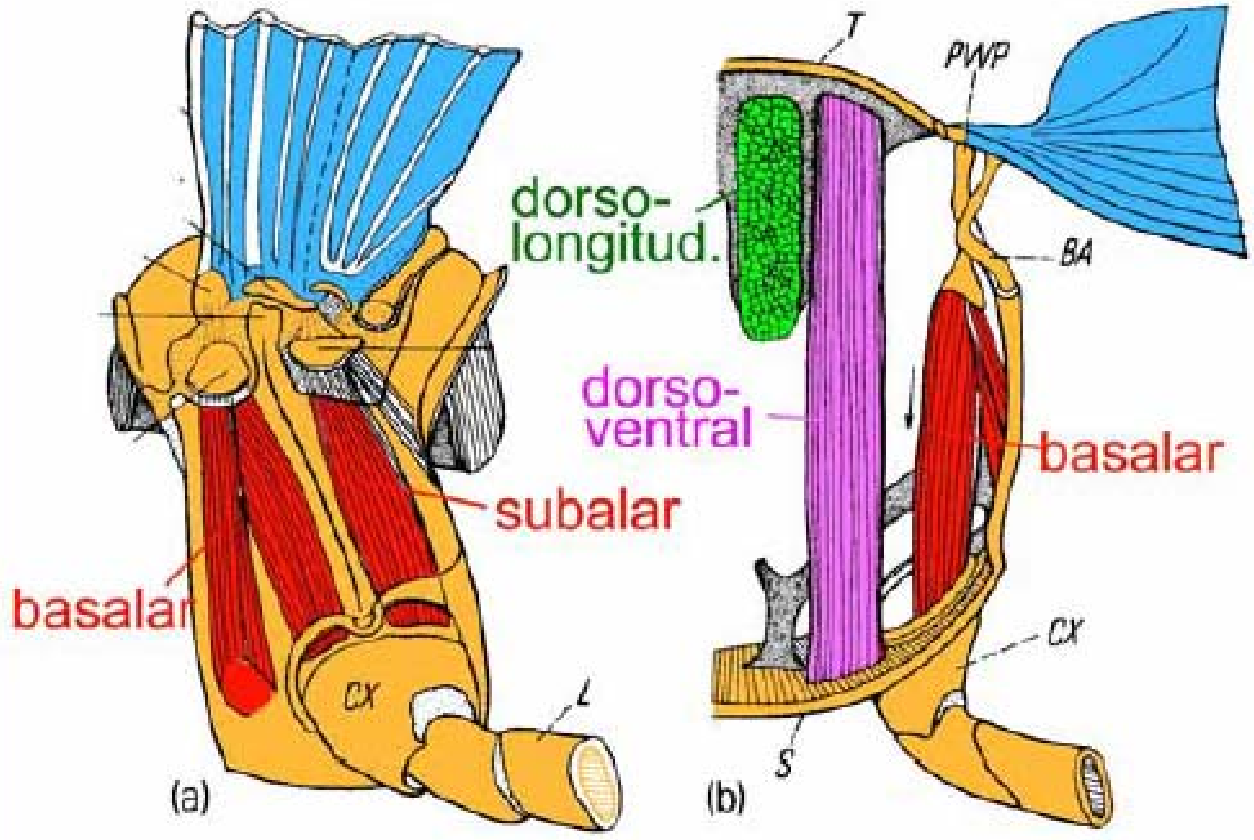
Podélné sv.

Dorzo-ventr. svaly



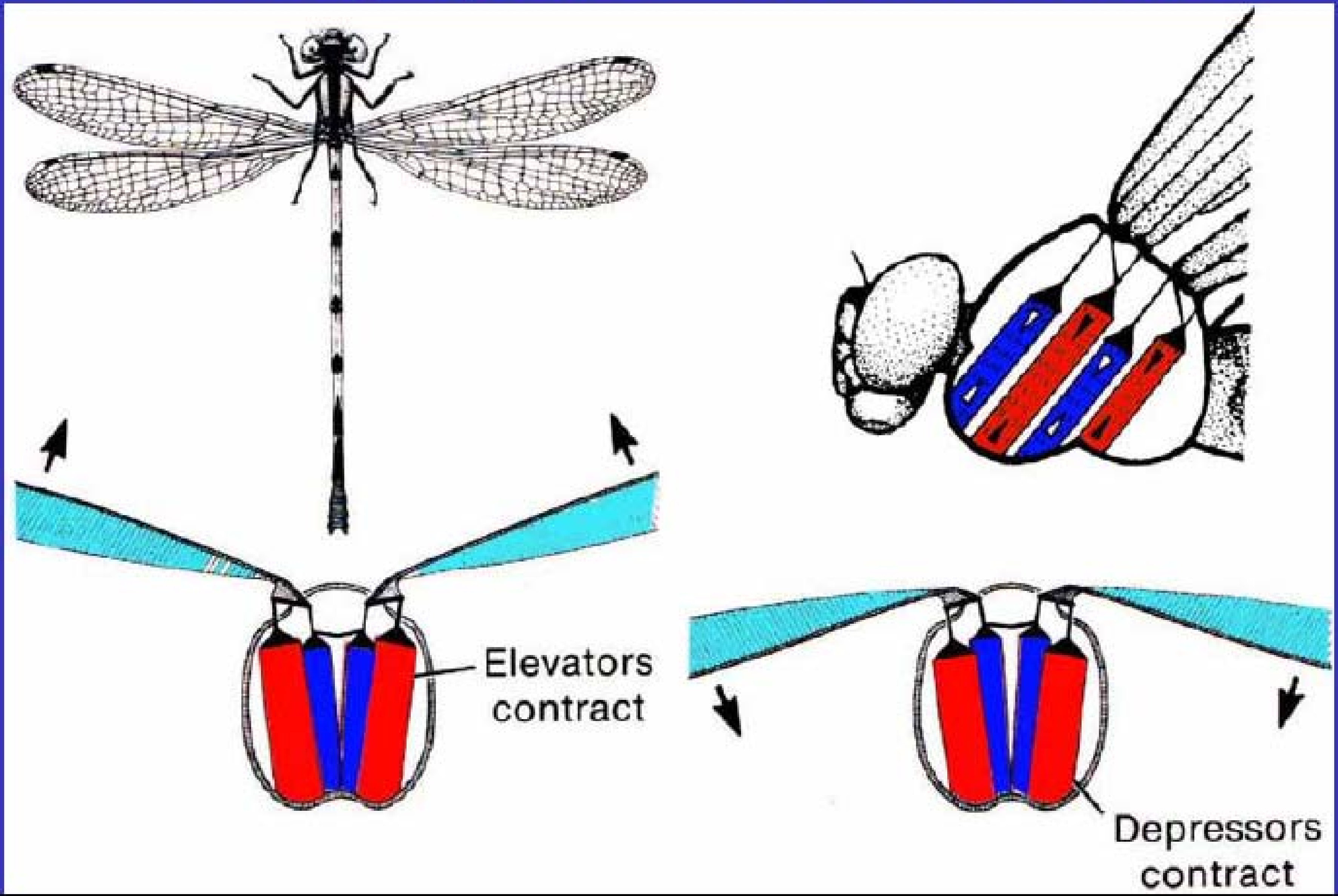
„Přepínací“
mechanismus

Direct flight muscles directly attach to the wing joint. They may power the wing or control wing rotation, deformation etc.

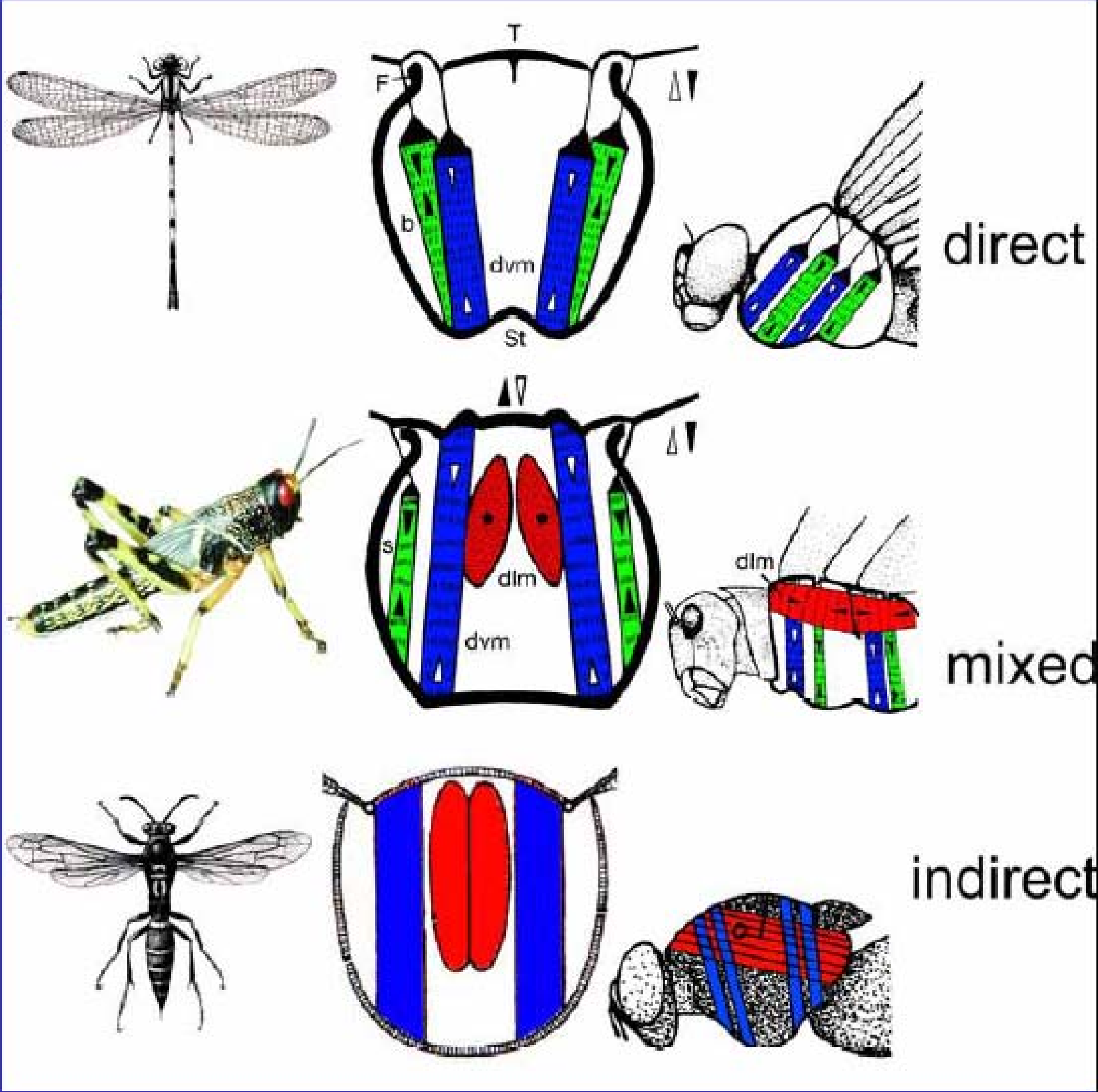


direct flight muscles

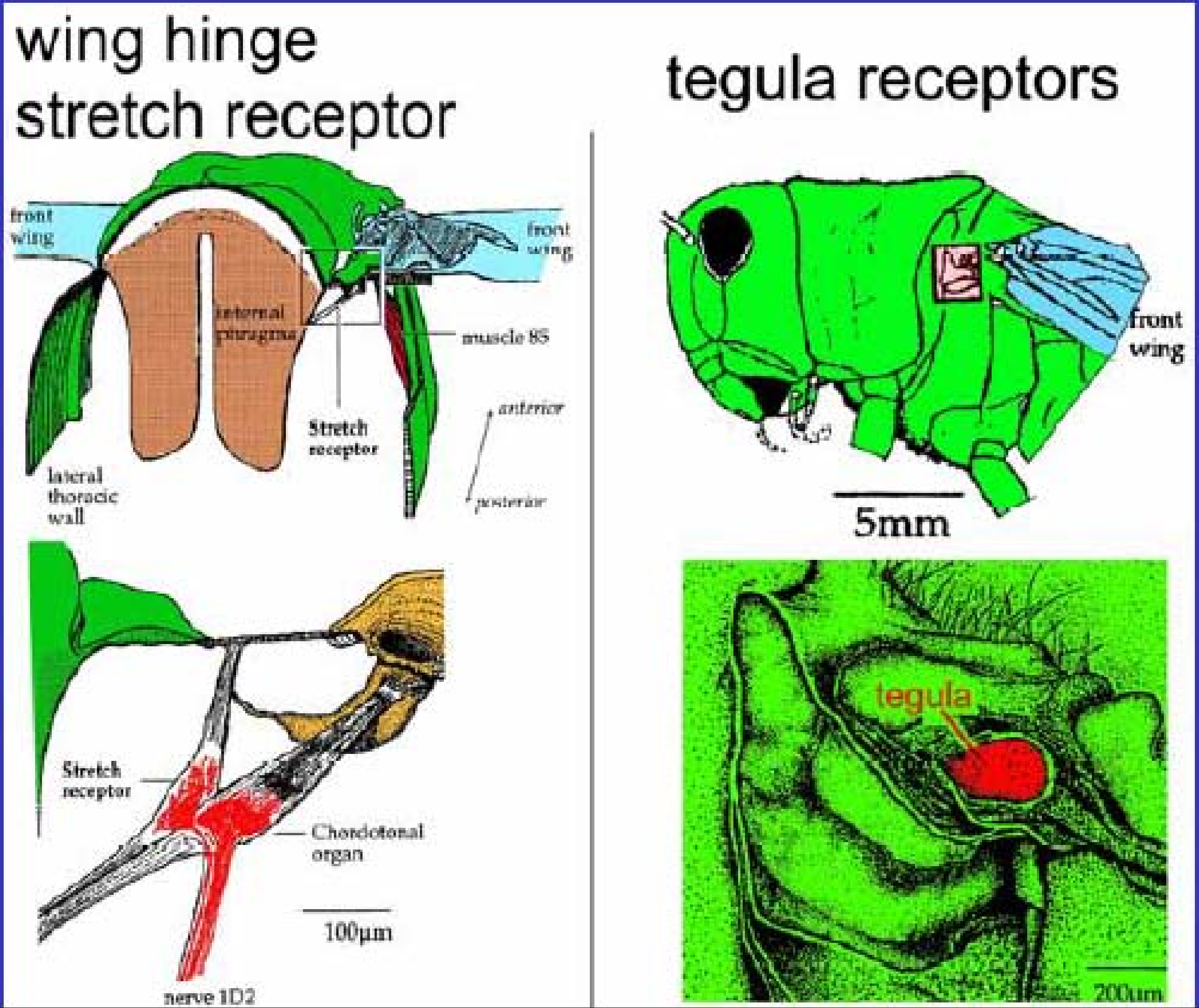
Odonata and Blattodea use direct muscles for wing upstroke and downstroke



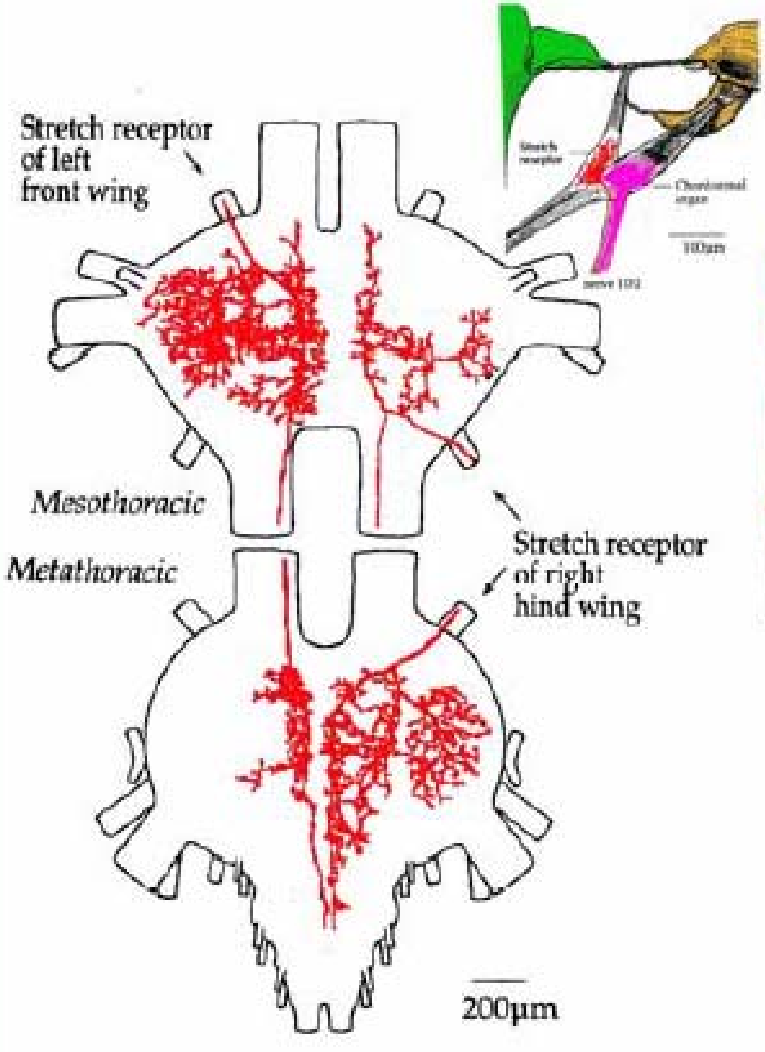
Many insects generate flight power using indirect flight muscles

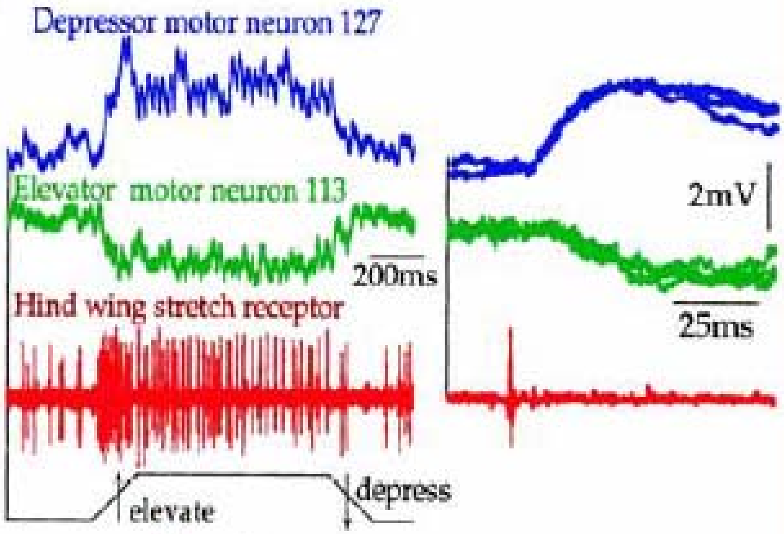


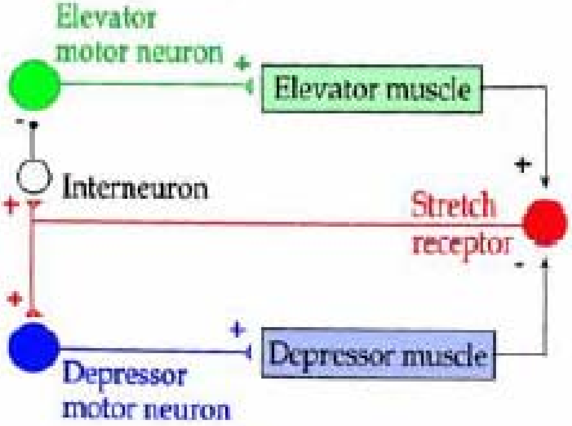
Stretch receptors and tegula receptors measure movement and position of the wings. Their action increases the wing beat frequency.



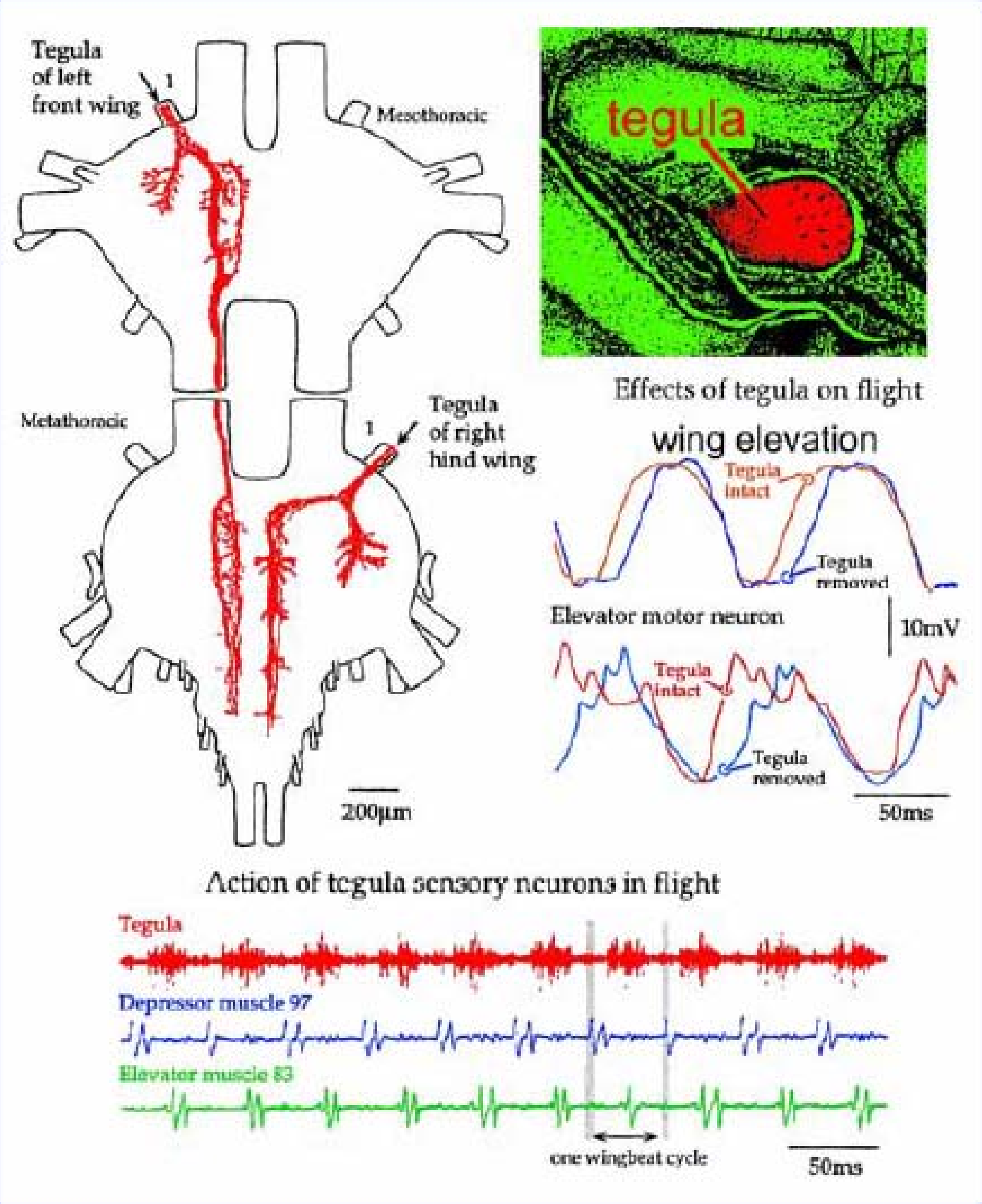
Stretch receptors are active during the upstroke. They inhibit elevator motor neurons and activate depressor neurons



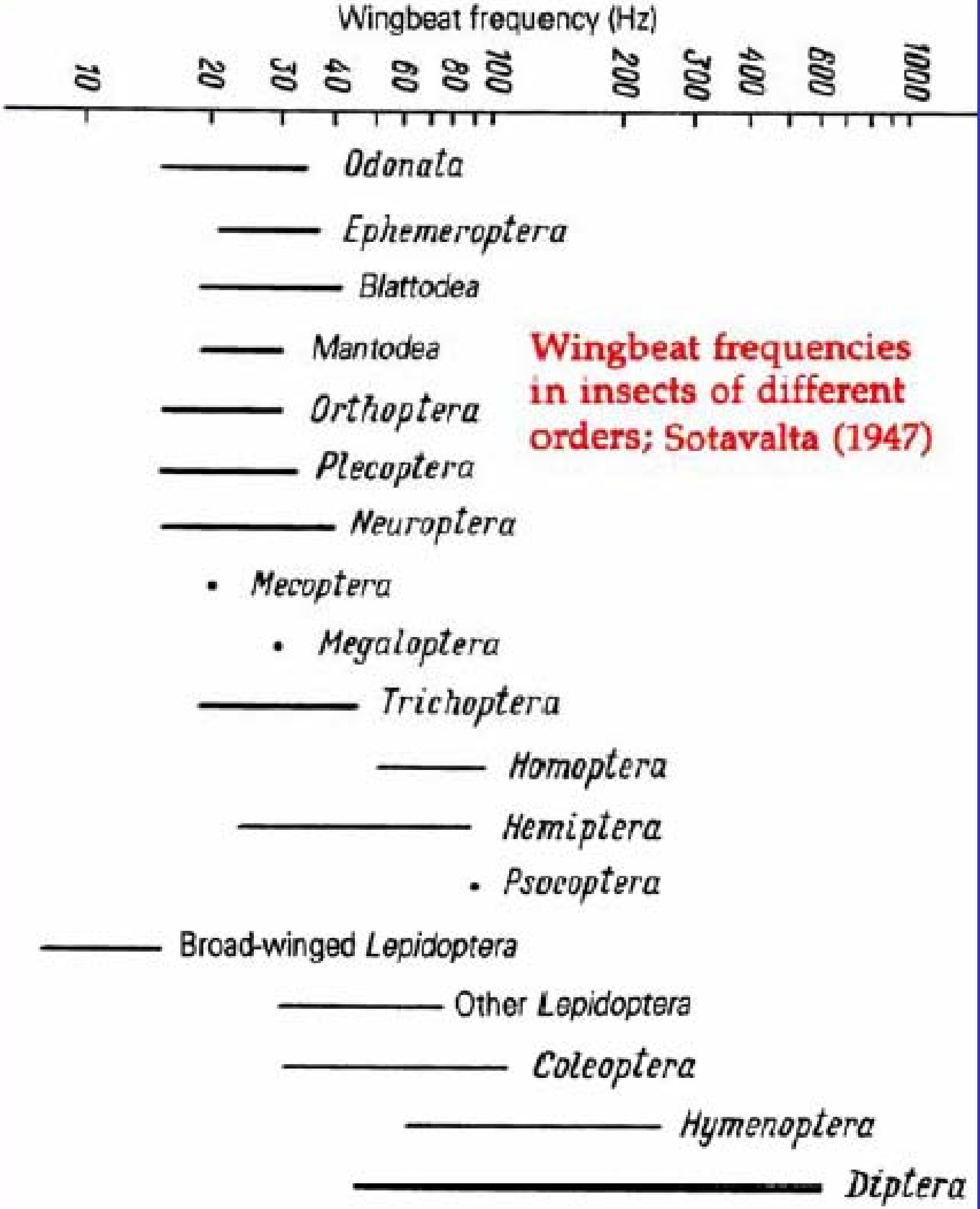




Tegular receptors are active during the downstroke. They excite elevator motor neurons.



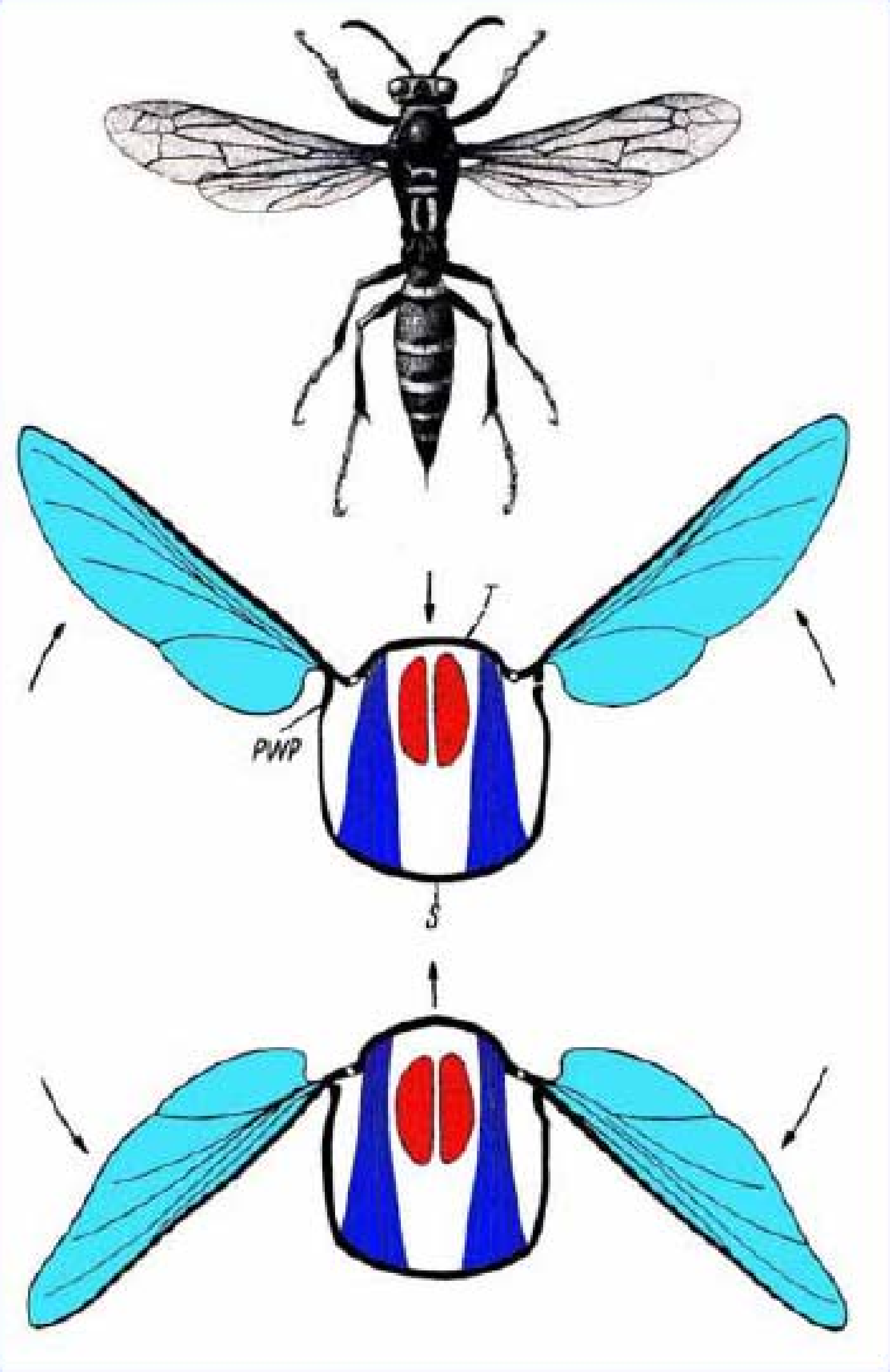
How do small insects (e.g. diptera, wasps) generate high wingbeat frequencies?



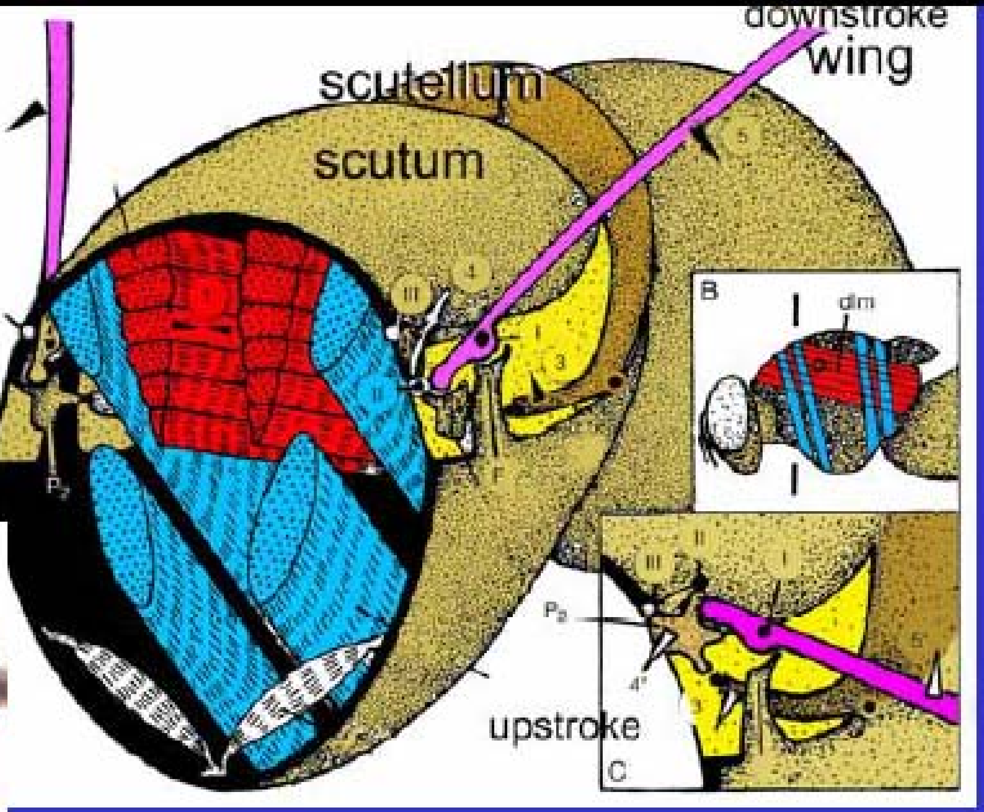
Wingbeat frequencies in insects of different orders; Sotavalta (1947)

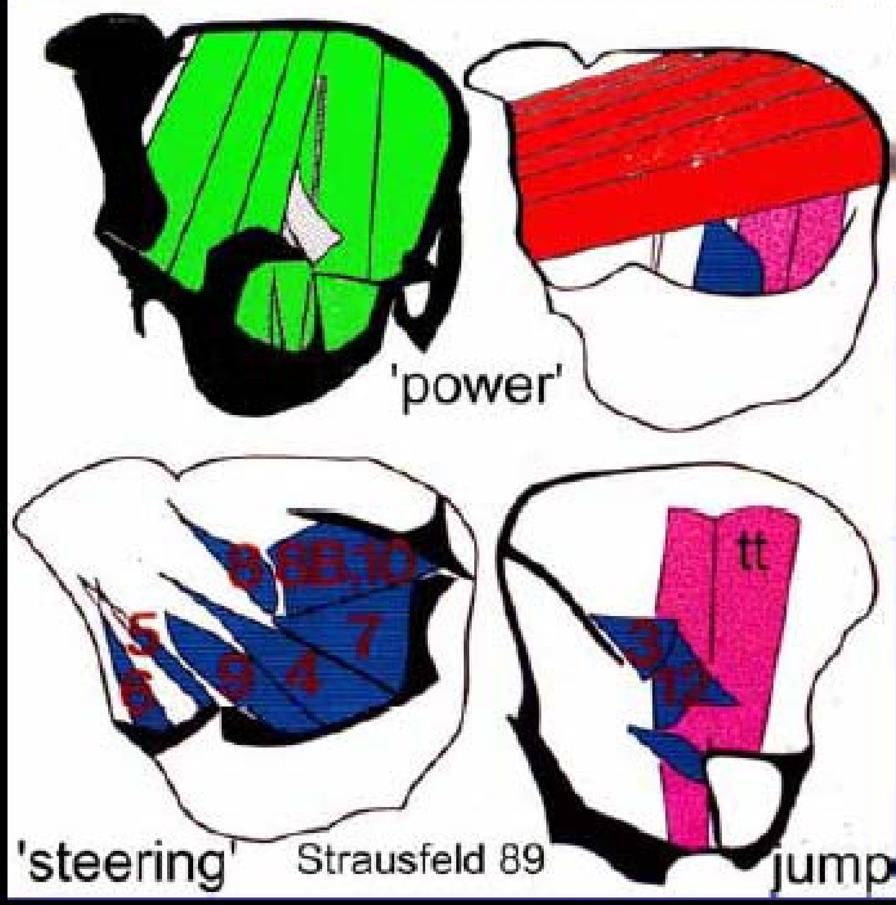
The indirect flight muscles of Diptera and Hymenoptera vibrate the thorax “box” at resonance frequencies.

These muscles are morphologically and functionally specialized (‘fibrillar muscles’)



Flies have prominent indirect flight muscles

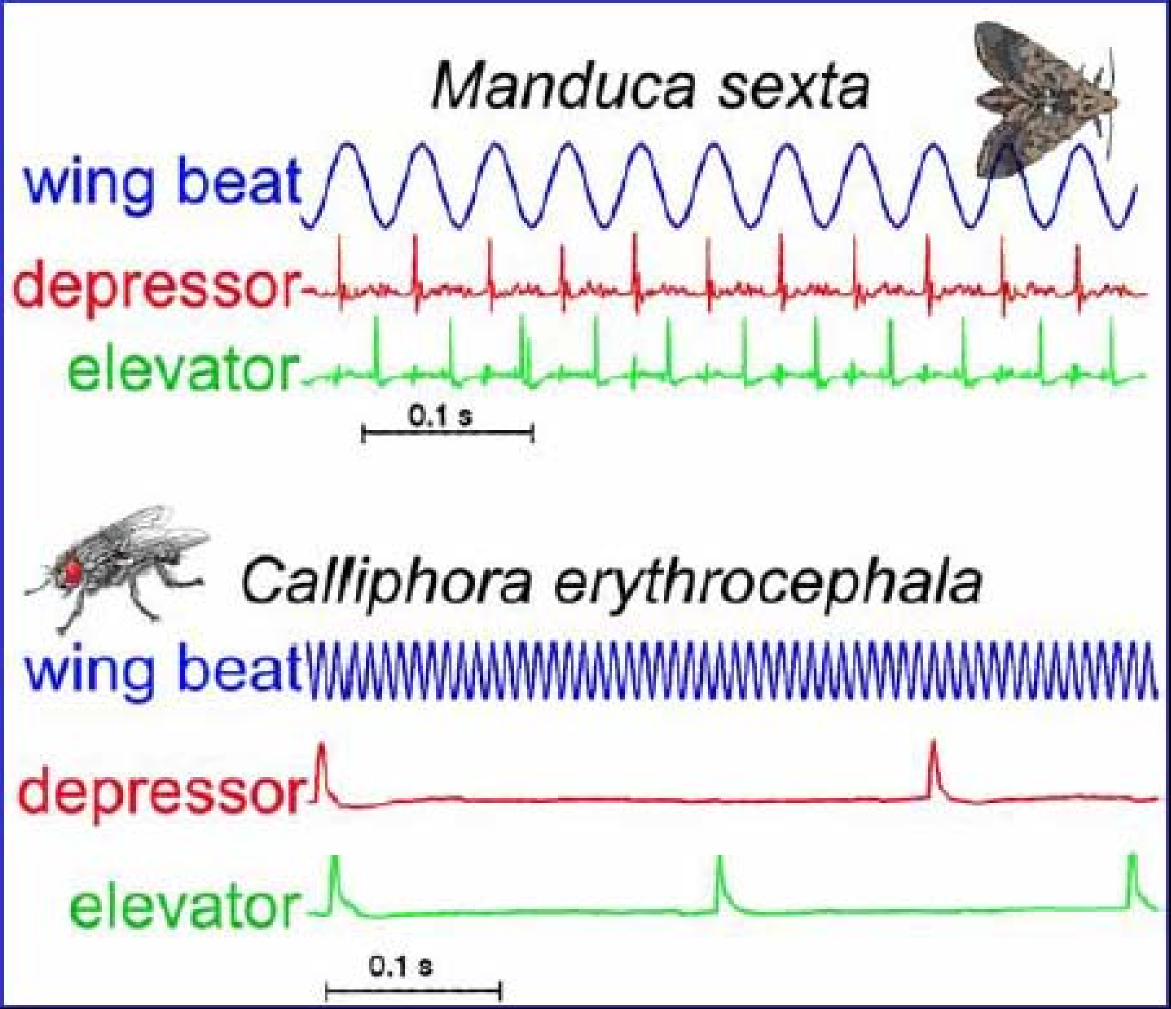




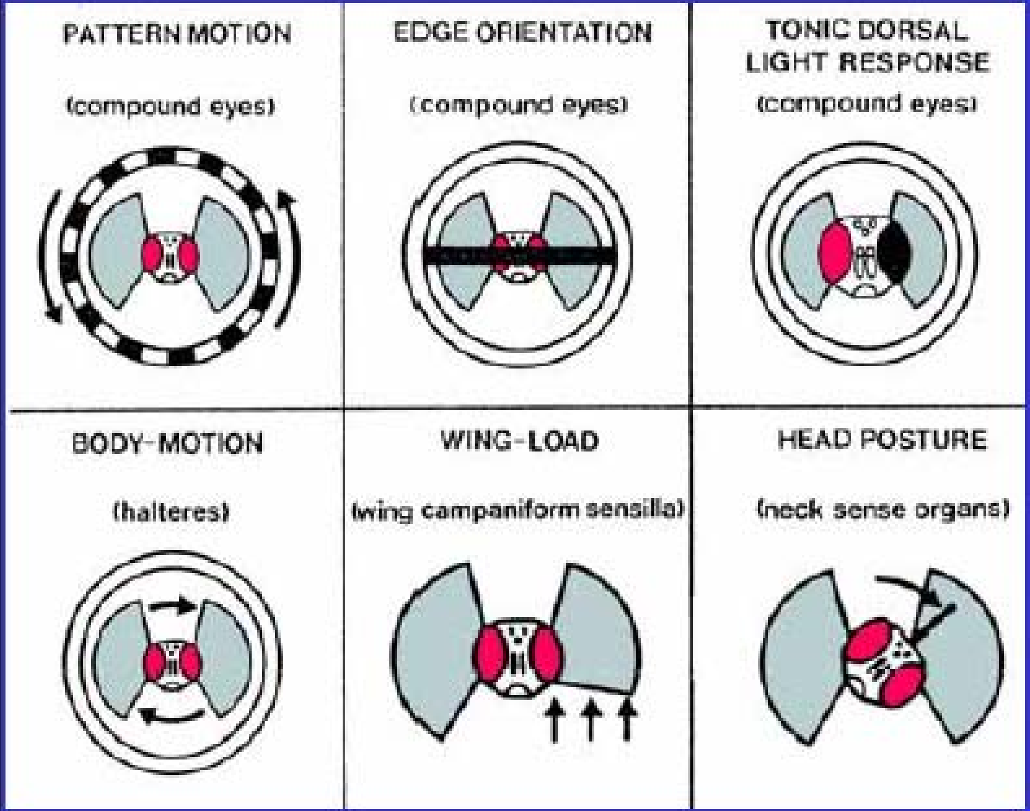
Strausfeld 89

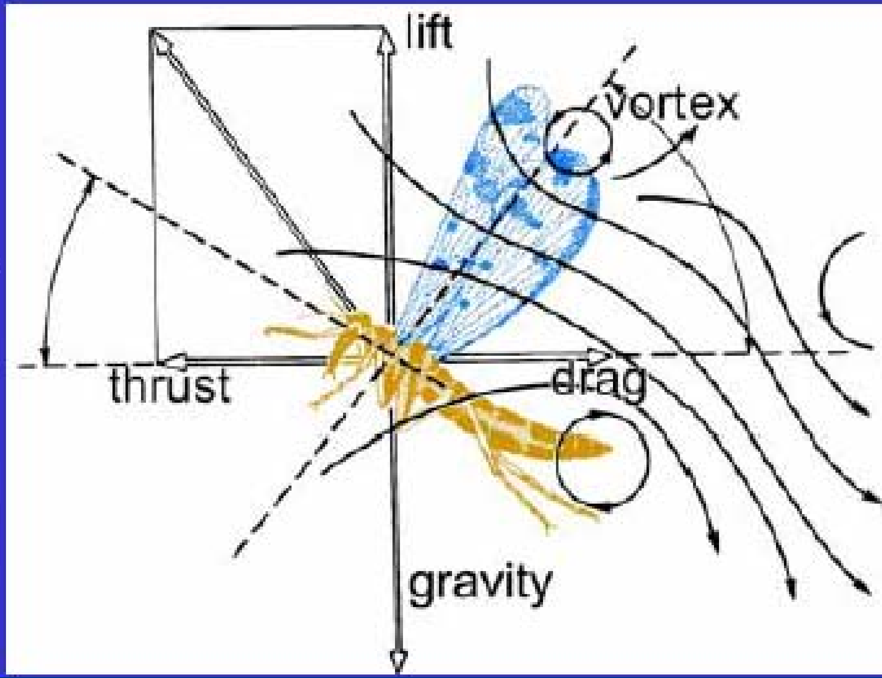
The wing joint comprises a ‘click’ mechanism that drives the wings

Fibrillar muscles are also called 'asynchronous' or 'myogenic' because they do not contract in synchrony with the motor neurons that supply them

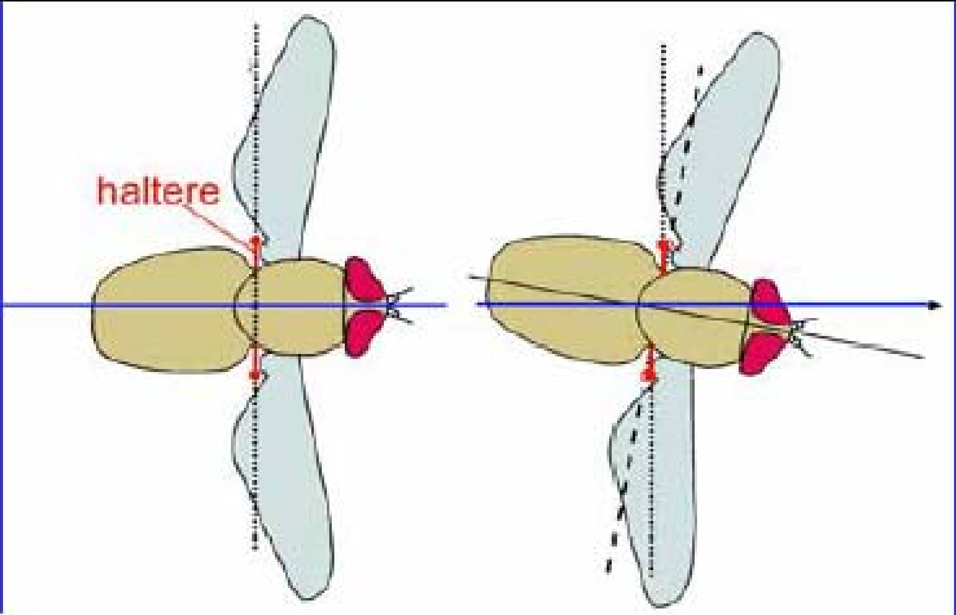


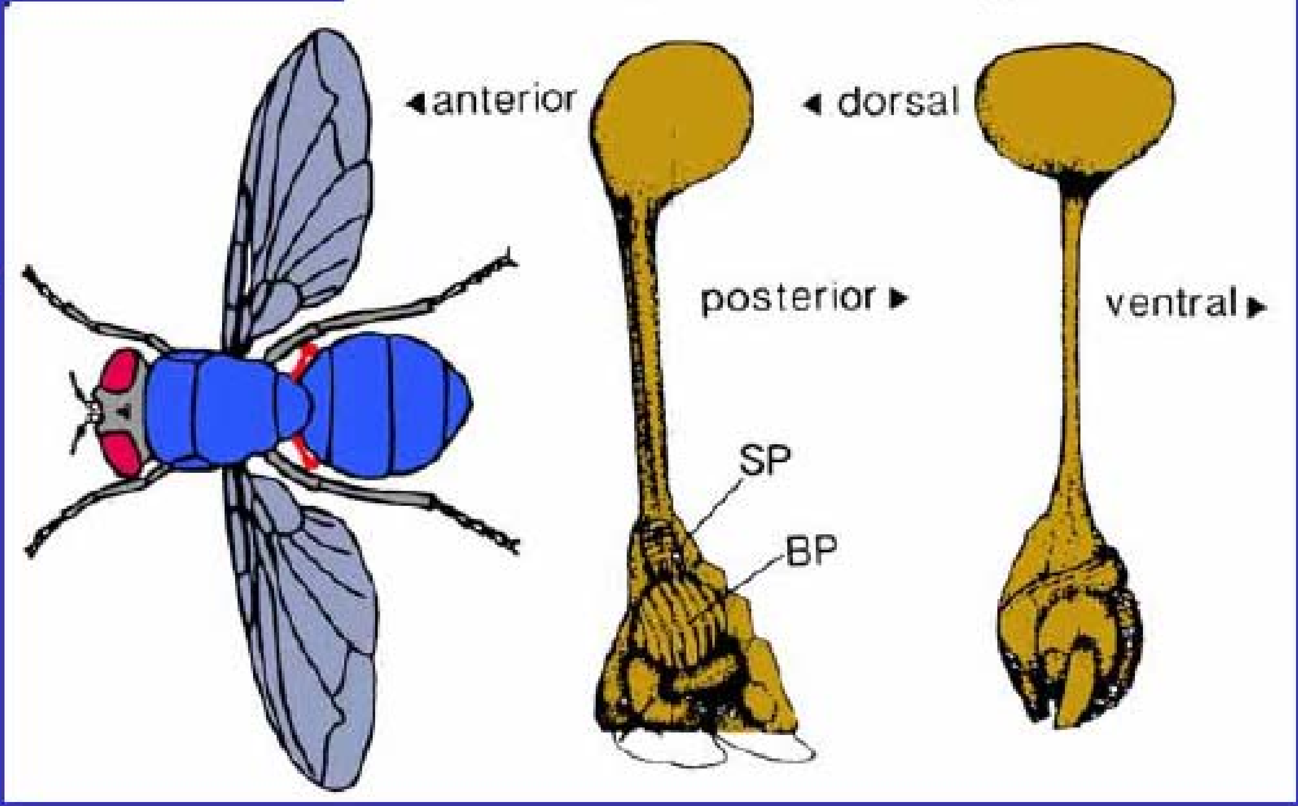
Wing load, air speed, wind direction, turbulence and other mechanical parameters are integrated with visual information (flow-fields, landmarks, targets)



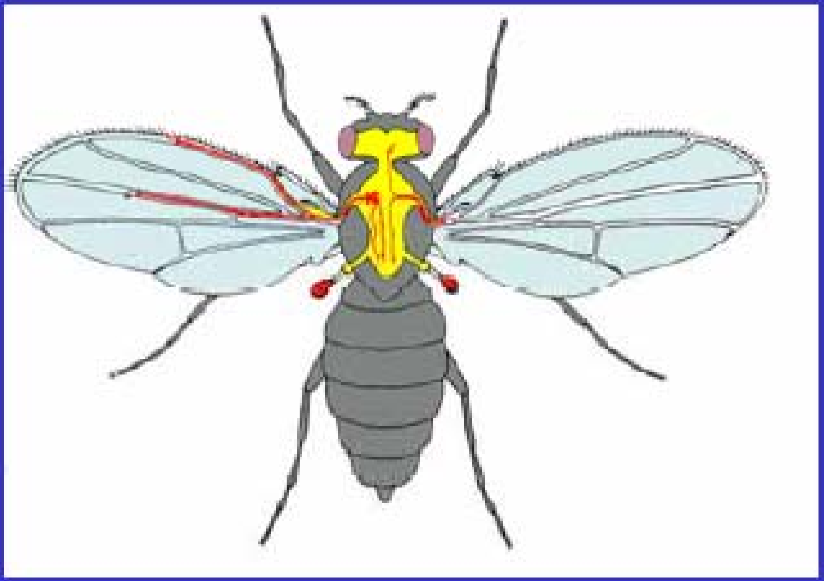


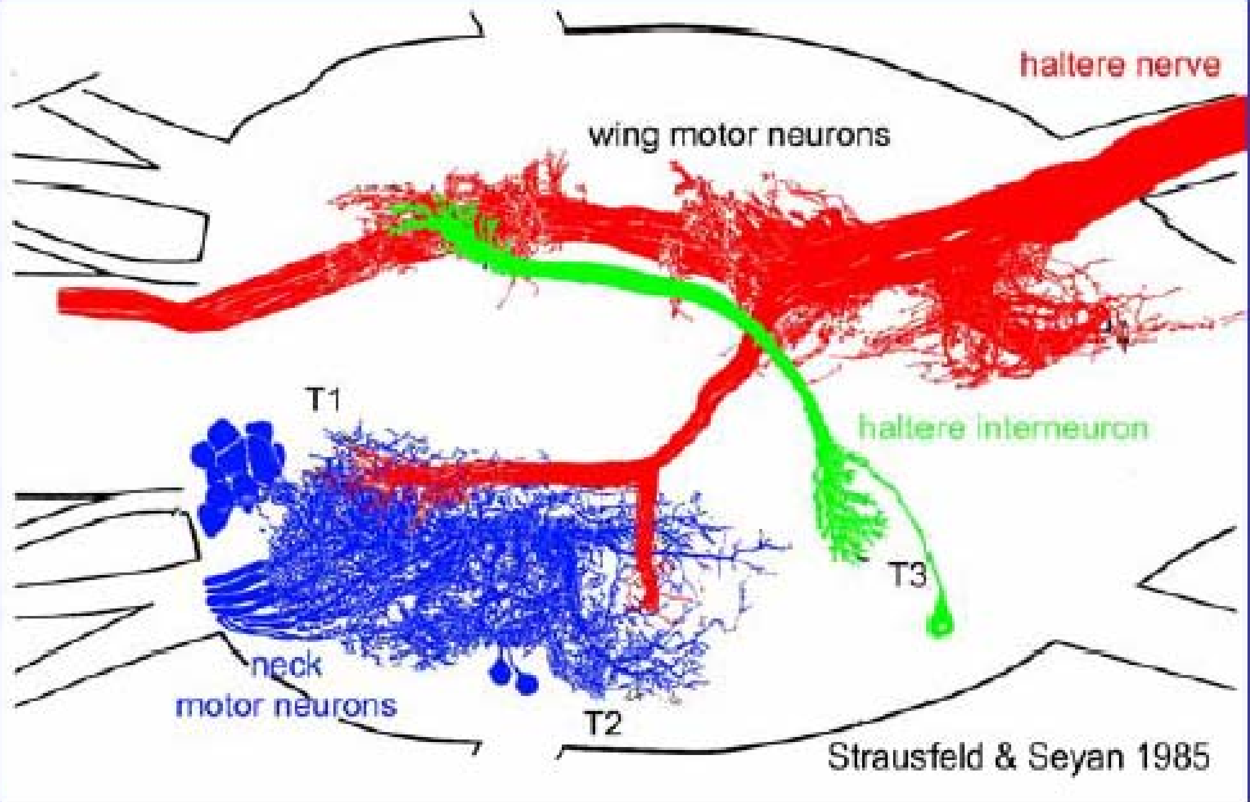
Diptera (flies) have halteres, modified hind wings that serve as sensory structures. They work like **gyroscopes** and measure accelerations.





Information from the halteres directly feeds to the wing motor neuropil





Strausfeld & Seyan 1985

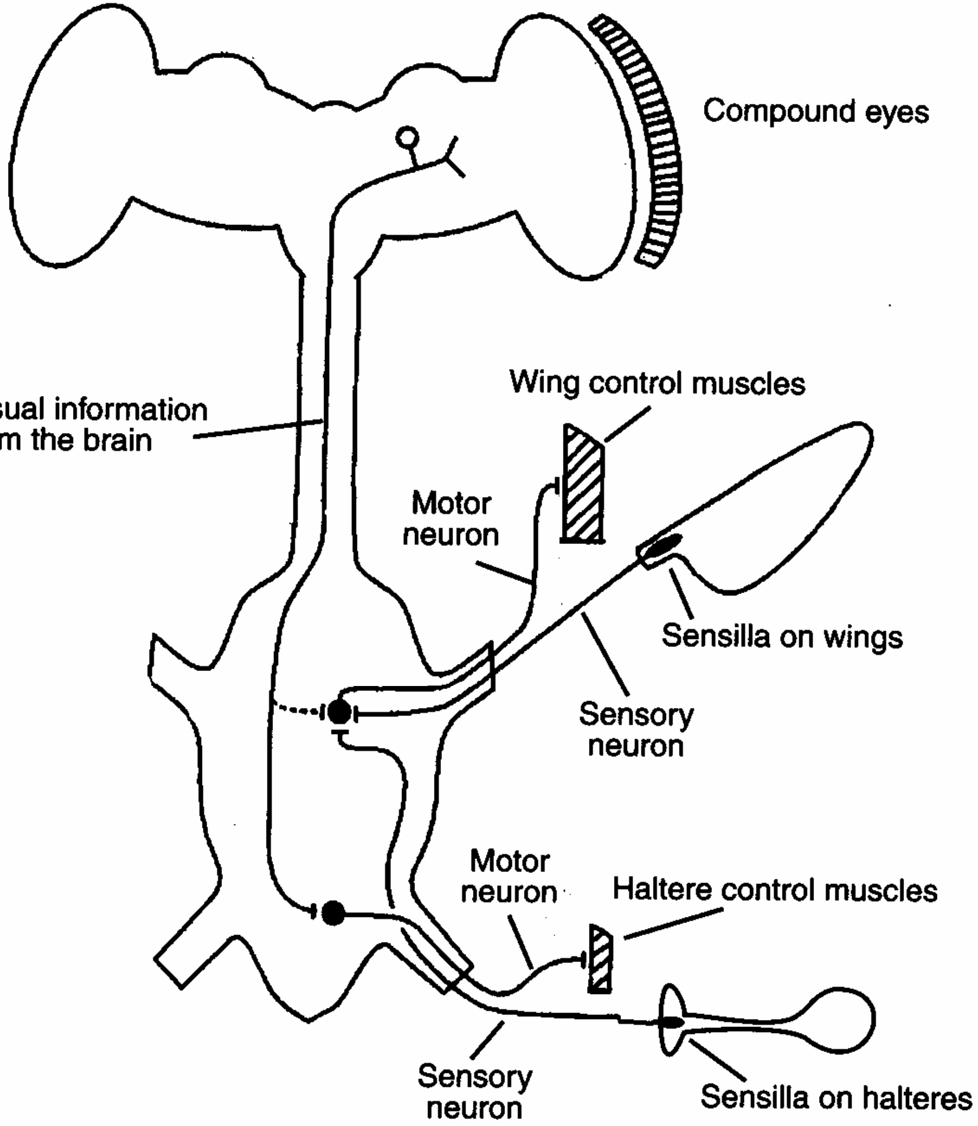
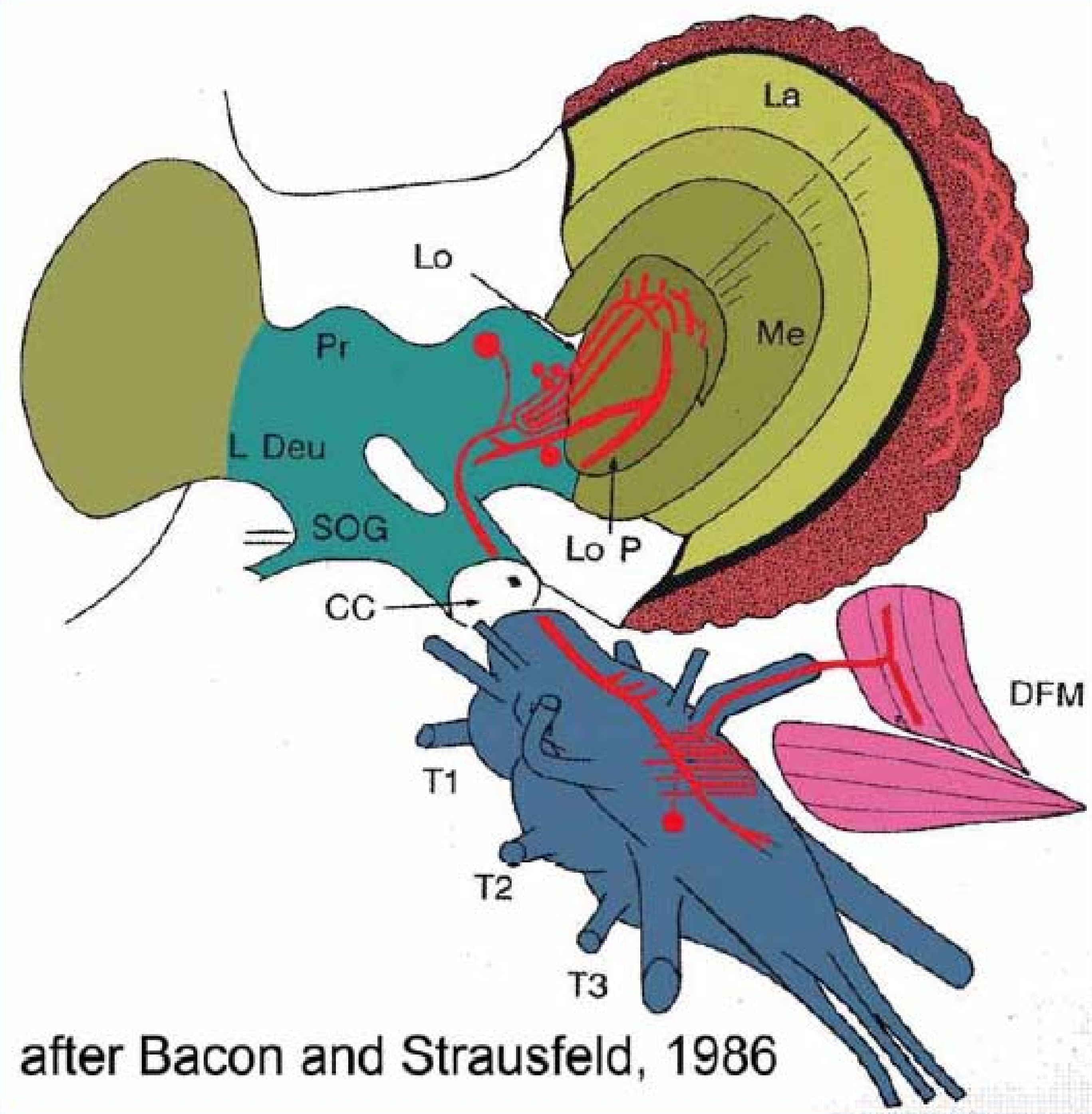


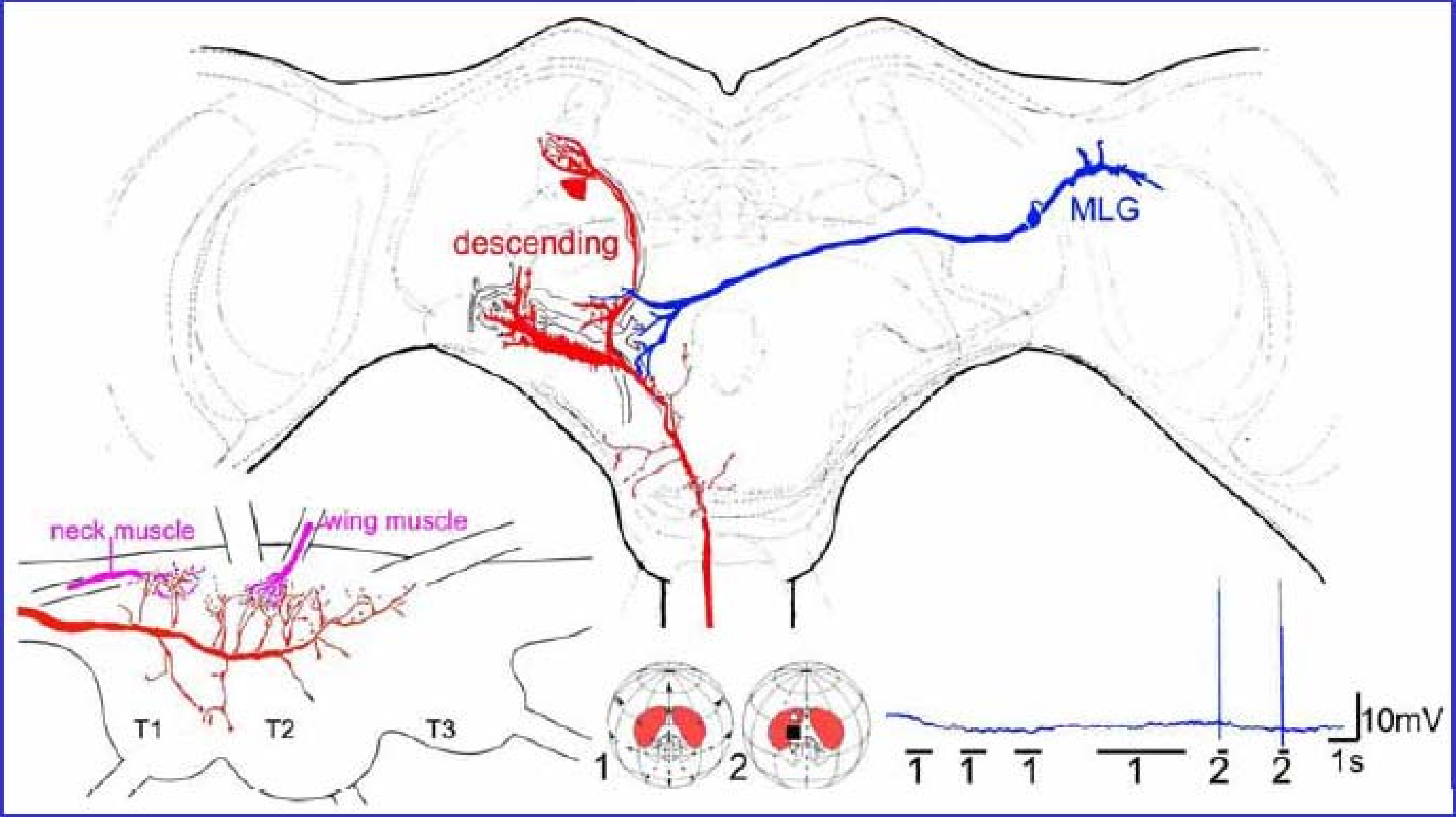
FIGURE 10.24 The mechanism of direct haltere control in the blowfly, *Calliphora*. The visual nterneurons from the compound eyes activate the haltere control muscles. Twisting movements of the alteres activate their sensilla that feed to the wing muscle motor neurons and modulate their control. Reprinted with permission from Chan, W. P., F. Prete, and M. H. Dickinson. Visual input to the effer- nt control system of a fly's "gyroscope." *Science* **280:** 289–292. Copyright 1998. American Association or the Advancement of Science.

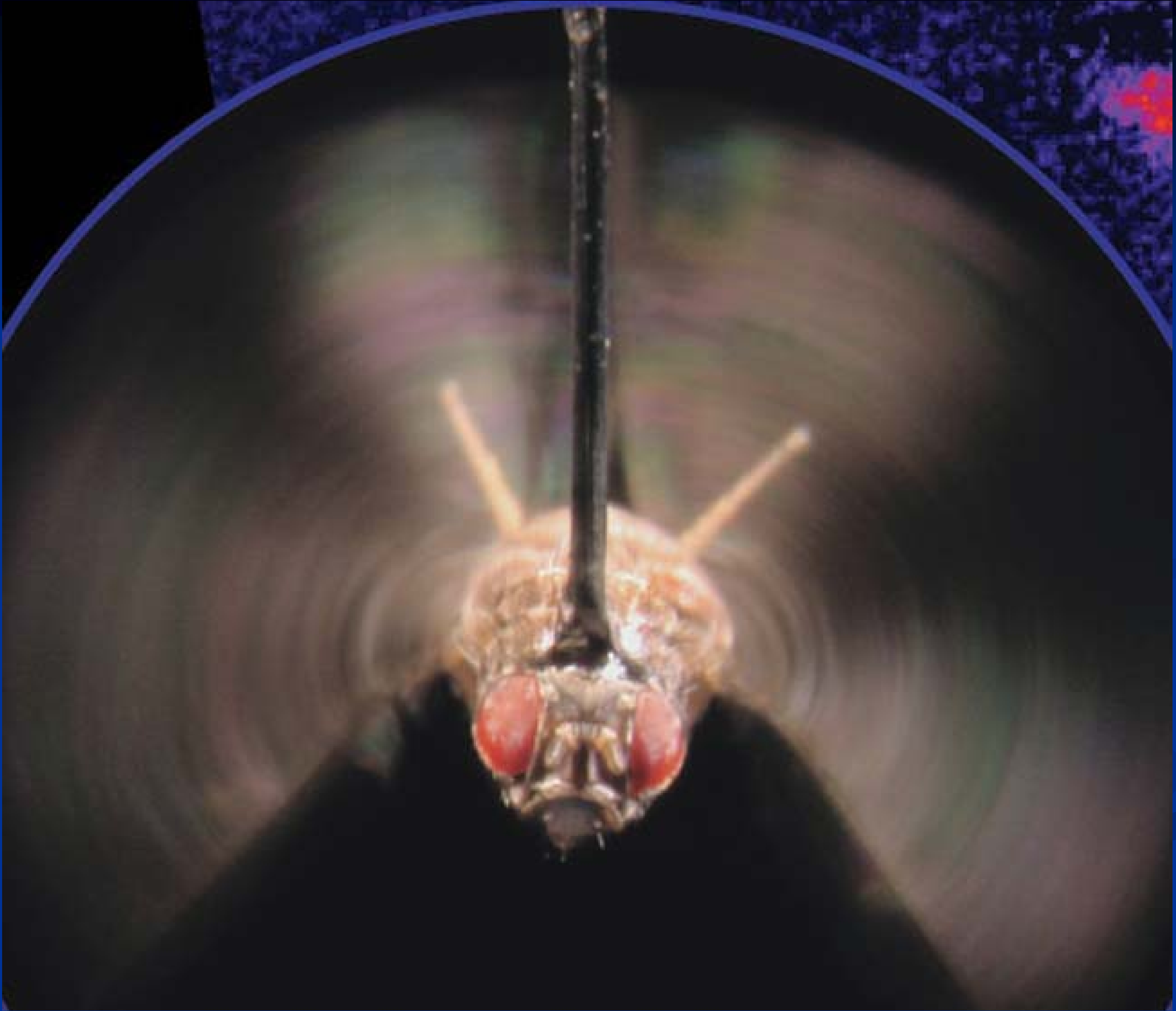
Visual input is required for flight control

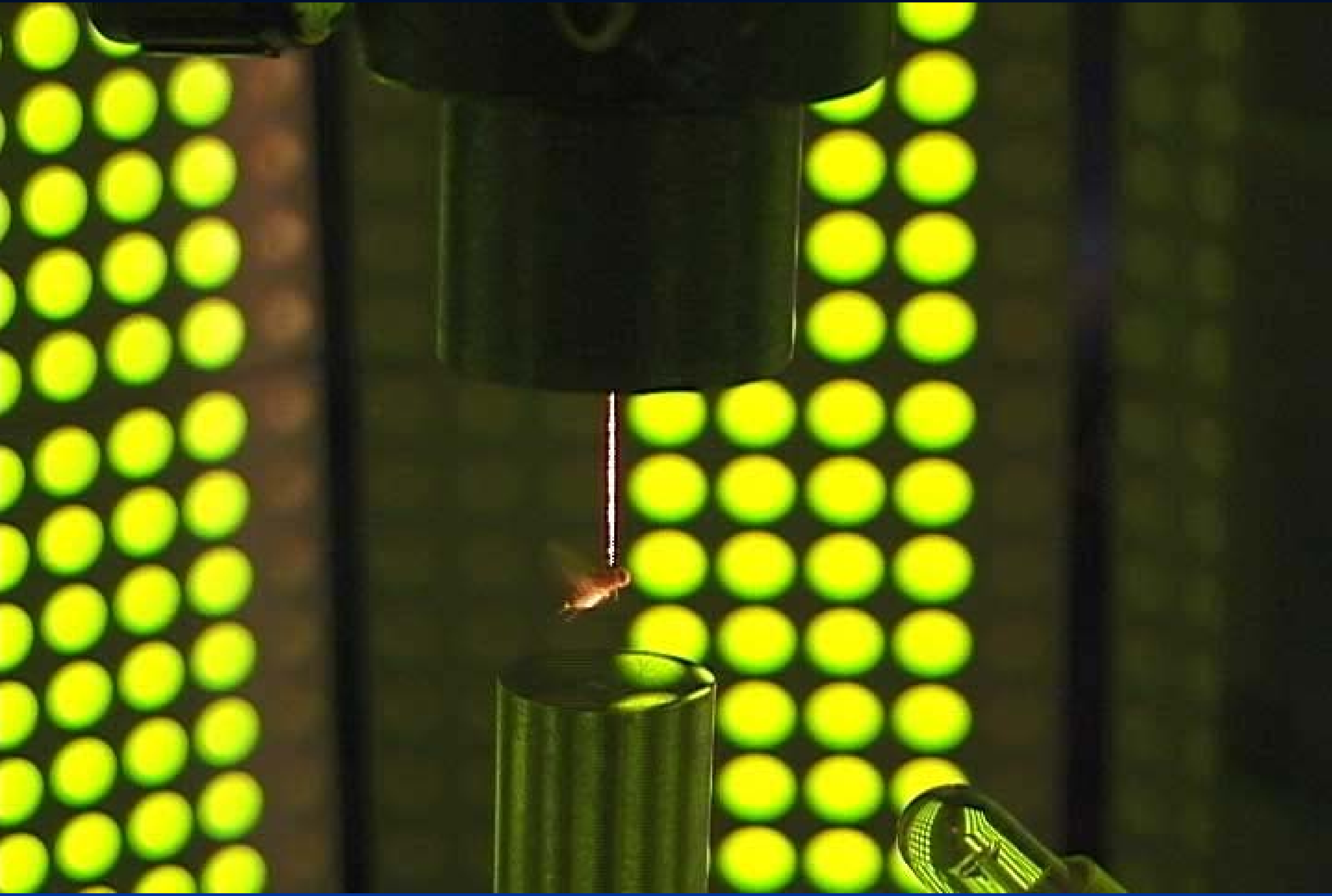


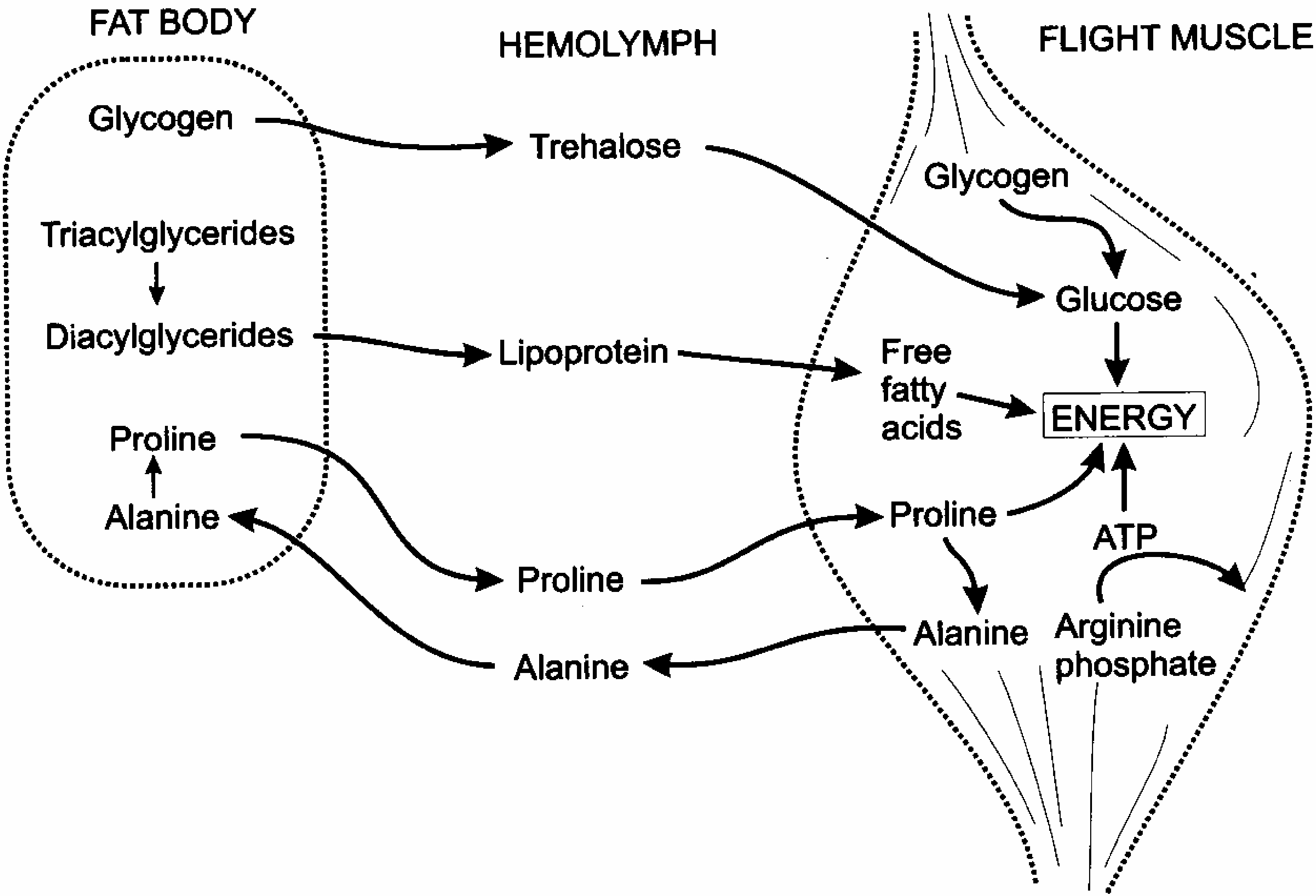
after Bacon and Strausfeld, 1986

Male flies (Calliphora) have a dedicated pathway that allows them to track female flies








FAT BODY
HEMOLYMPH
FLIGHT MUSCLE
Glycogen
Trehalose
Glycogen
Triacylglycerides
Diacylglycerides
Lipoprotein
Glucose
Free fatty acids
ENERGY
Proline
Alanine
Proline
Proline
ATP
Alanine
Alanine
Arginine phosphate