Insects and their muscles

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

Taken by Firooo2, flagstaffotos.com.au

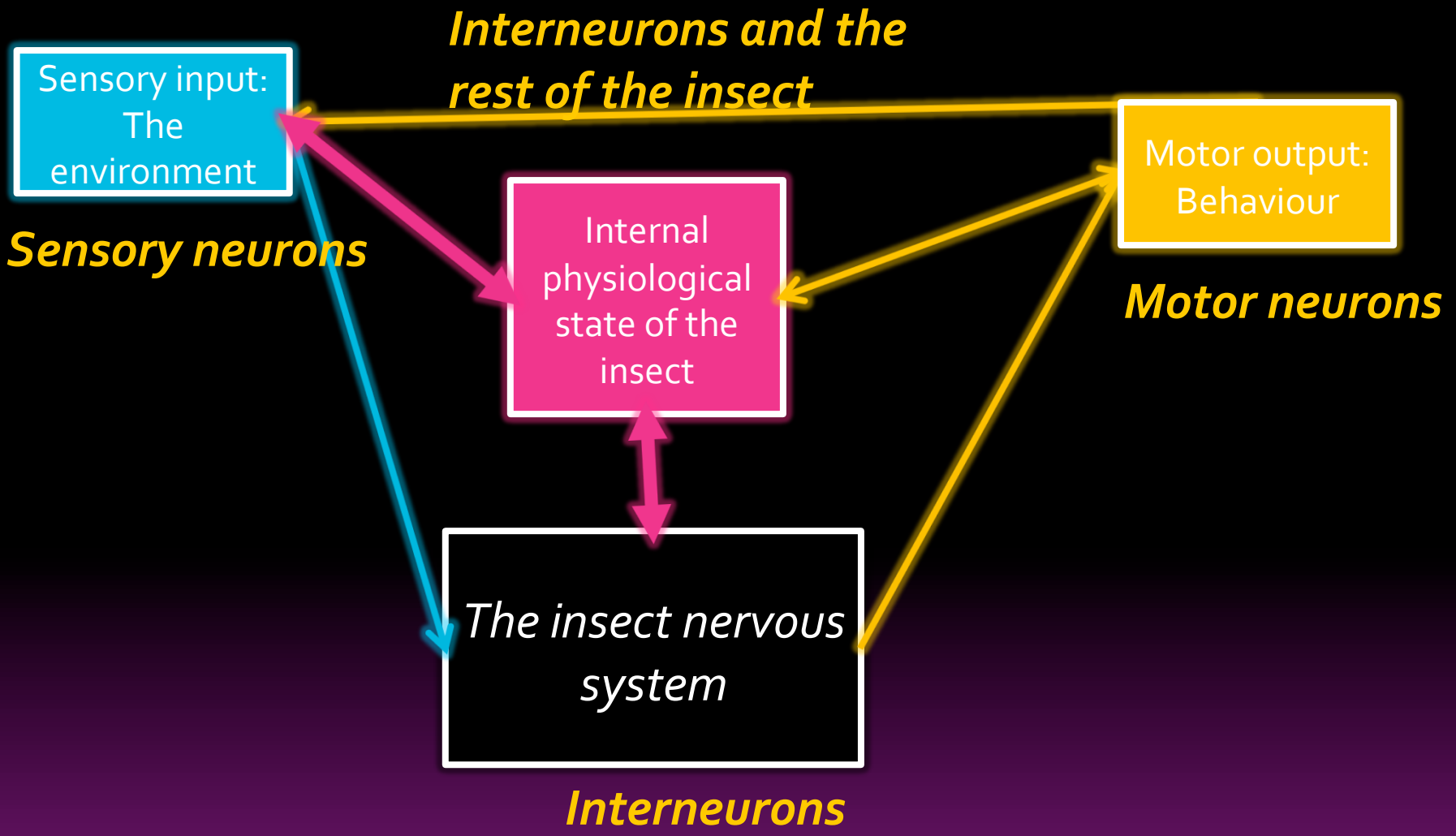
- Angelique Paulk

Objectives

- What is the motor system?
- What is muscle?
- How do insects move?
- What is synchronous and asynchronous muscle?

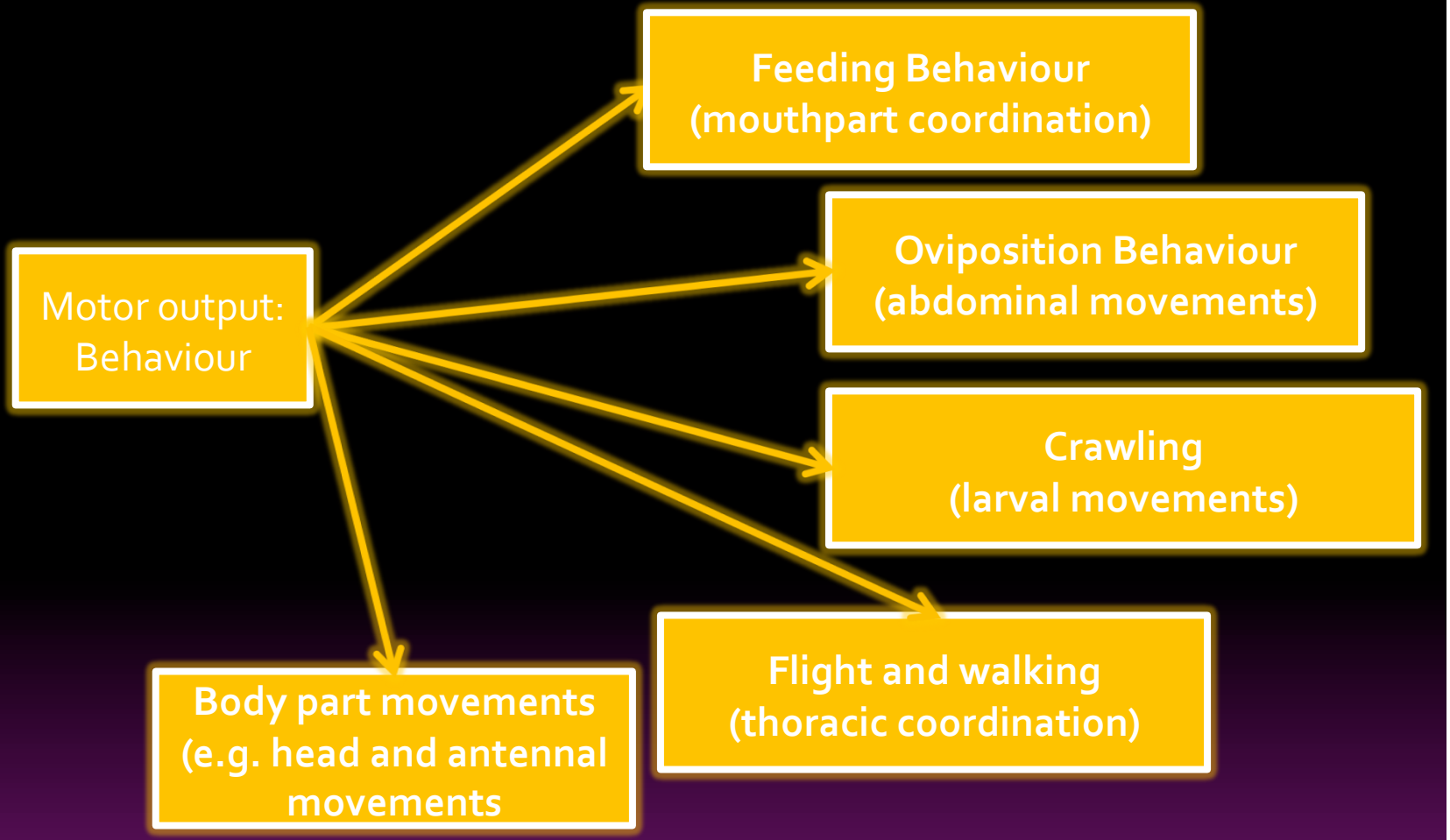
http://en.wikipedia.org/wiki/GNU_Free_Documentation_License
Taken by Firo002, flagstaffotos.com.au

The ‘black box’of the nervous system



How is the nervous system wired?

Motor output: where behaviour is produced

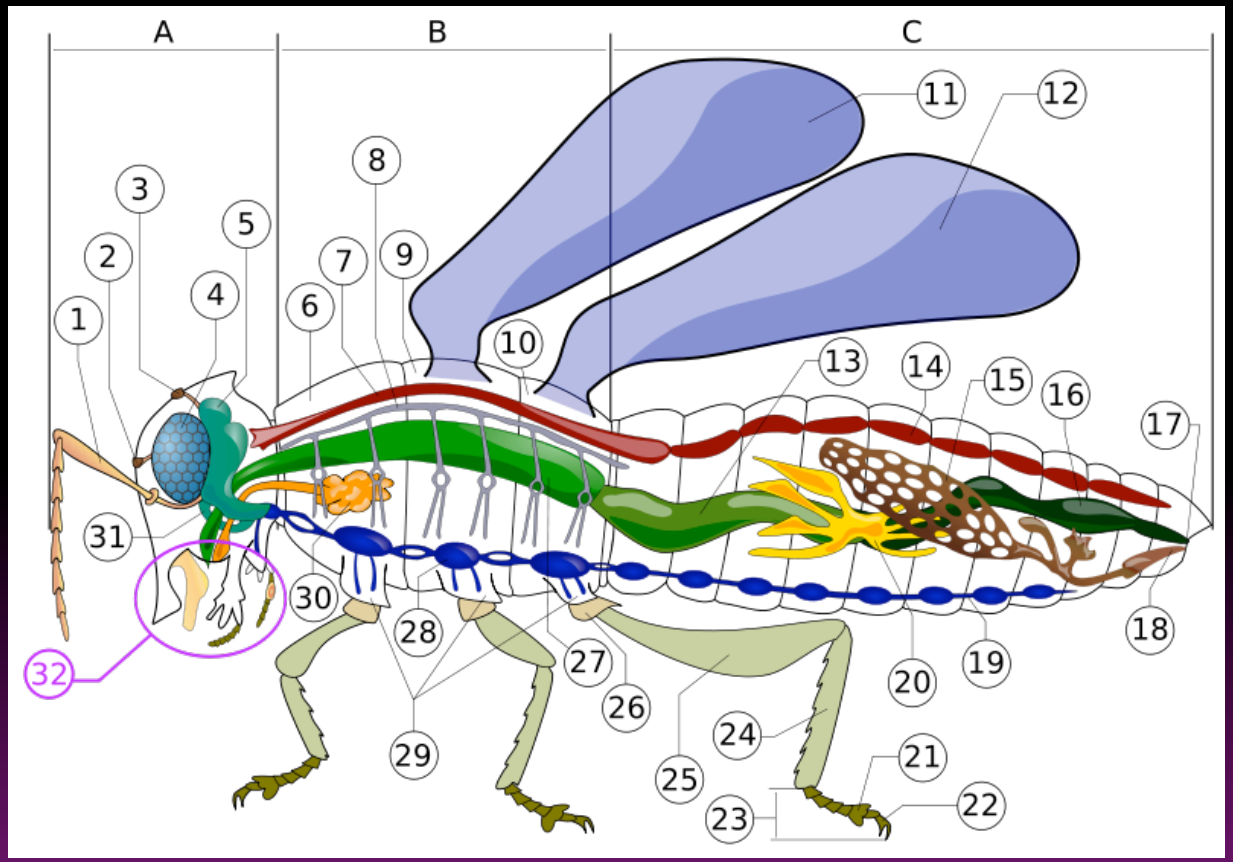


The motor output can produce a variety of different types of behavior depending on the sensory input and the physiological state of the animal

The insect nervous system

1. A brain (number 5)
2. The subesophageal ganglion (number 31)
3. Three thoracic ganglia (number 29) (the prothroacic, mesothoracic, and metathoracic ganglia)
4. A chain of abdominal ganglia (beads near 19)

All of these structures are connected by nerves called connectives (number 19)



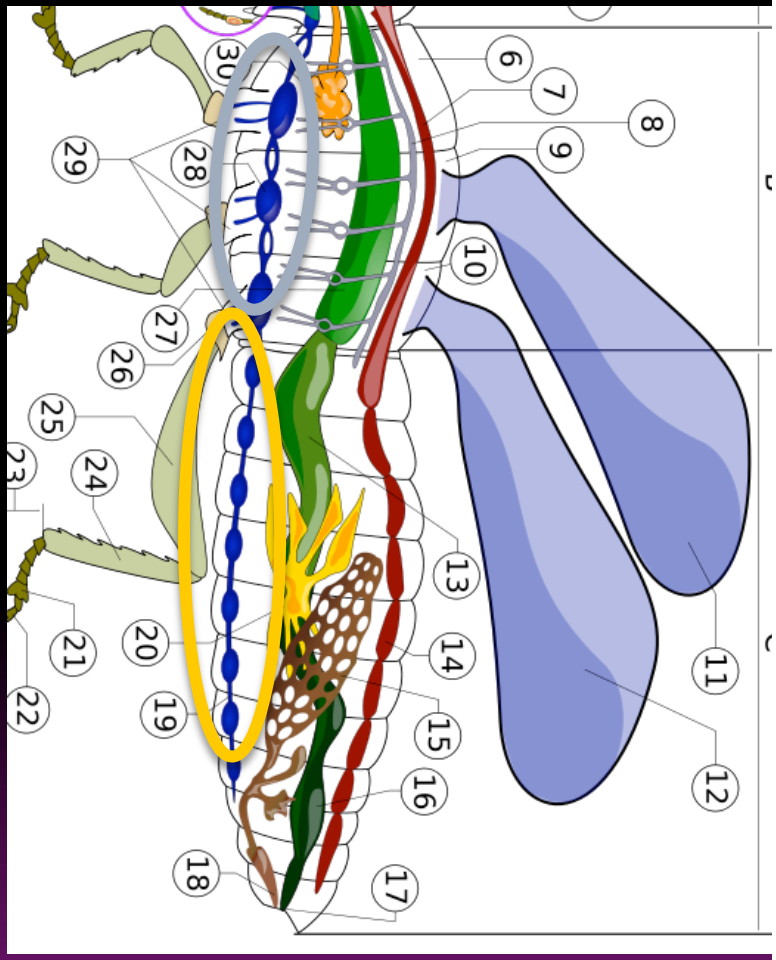
A. Head
B. Thorax
C. Abdomen

Piotr Jaworski, PioM, Wikipedia Commons http://en.wikipedia.org/wiki/Insect

Within the nervous system: the thoracic and abdominal ganglia

The layout of the thoracic and abdominal ganglia do follow a certain pattern:

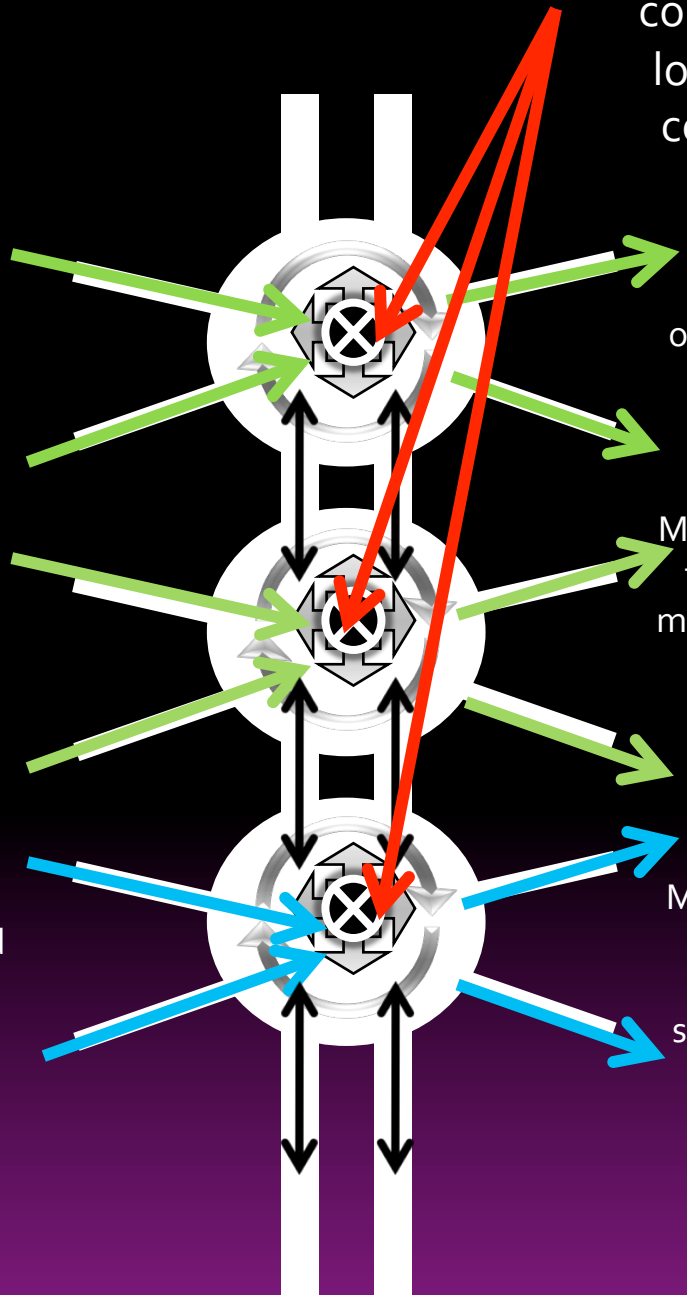
- Sensory input is often separated from motor output
- The thoracic ganglia (or fused into a single thoracic ganglion) tends to be more developed compared to the abdominal ganglion because control of the wings (11,12) and legs (is in the thorax
- There is an orientation in the thorax: the more distal the sensory input to the thoracic ganglion, the more lateral and posterior the projections (**figure**)
- The thoracic ganglion: sensory input includes mechanosensory, auditory, and gustatory input (from the tarsi)
- Abdominal ganglia: sensory input is generally mechanosensory input



Piotr Jaworski, PioM, Wikipedia Commons
http://en.wikipedia.org/wiki/Insect

Wiring the thoracic ganglion

Interneurons: allowing the circuit to operate, gating the sensory input to control the motor output, allowing locomotion to happen along with coordination between segments



Sensory input from the front leg and neck

Motor neuron output to the front leg and neck

Prothoracic ganglion

Sensory input from the middle leg, mesothorax, and first pair of wings

Motor neuron output to the middle leg, mesothorax, and first pair of wings

Mesothoracic ganglion

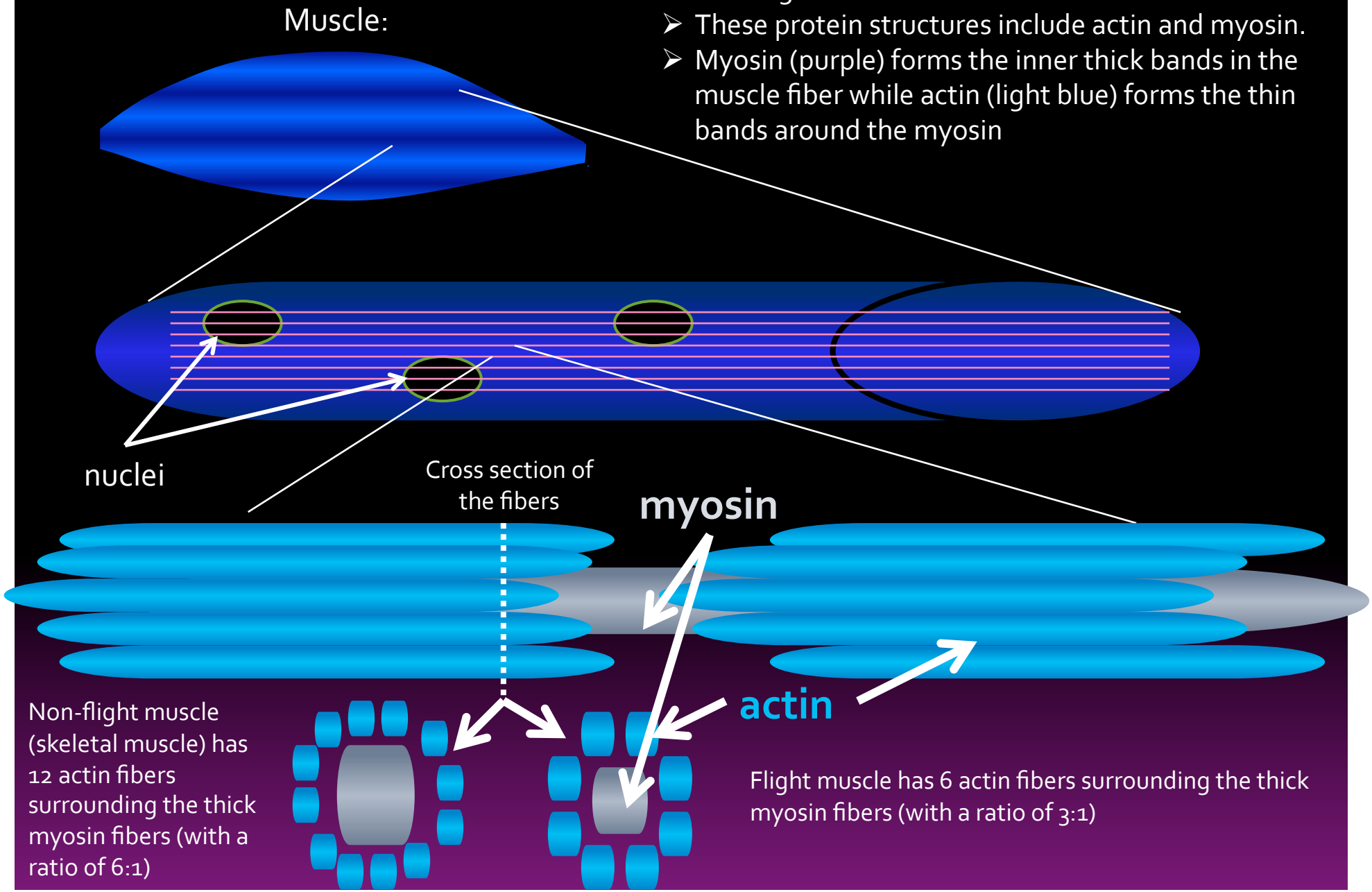
Sensory input from the middle leg, metathorax, and second pair of wings

Motor neuron output to the middle leg, metathorax, and second pair of wings

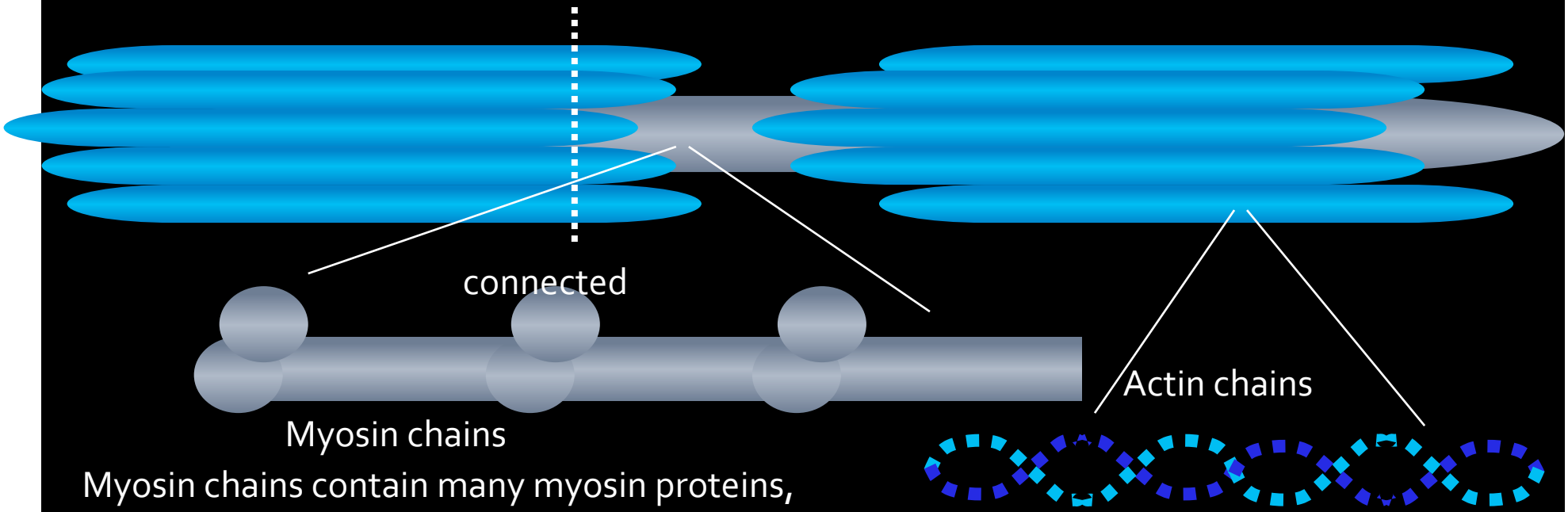
Metathoracic ganglion

Insect muscles

- Muscles are composed of multinucelate cells with extensive internal protein structures arranged along the length of the fiber.
- These protein structures include actin and myosin.
- Myosin (purple) forms the inner thick bands in the muscle fiber while actin (light blue) forms the thin bands around the myosin



Insect muscles

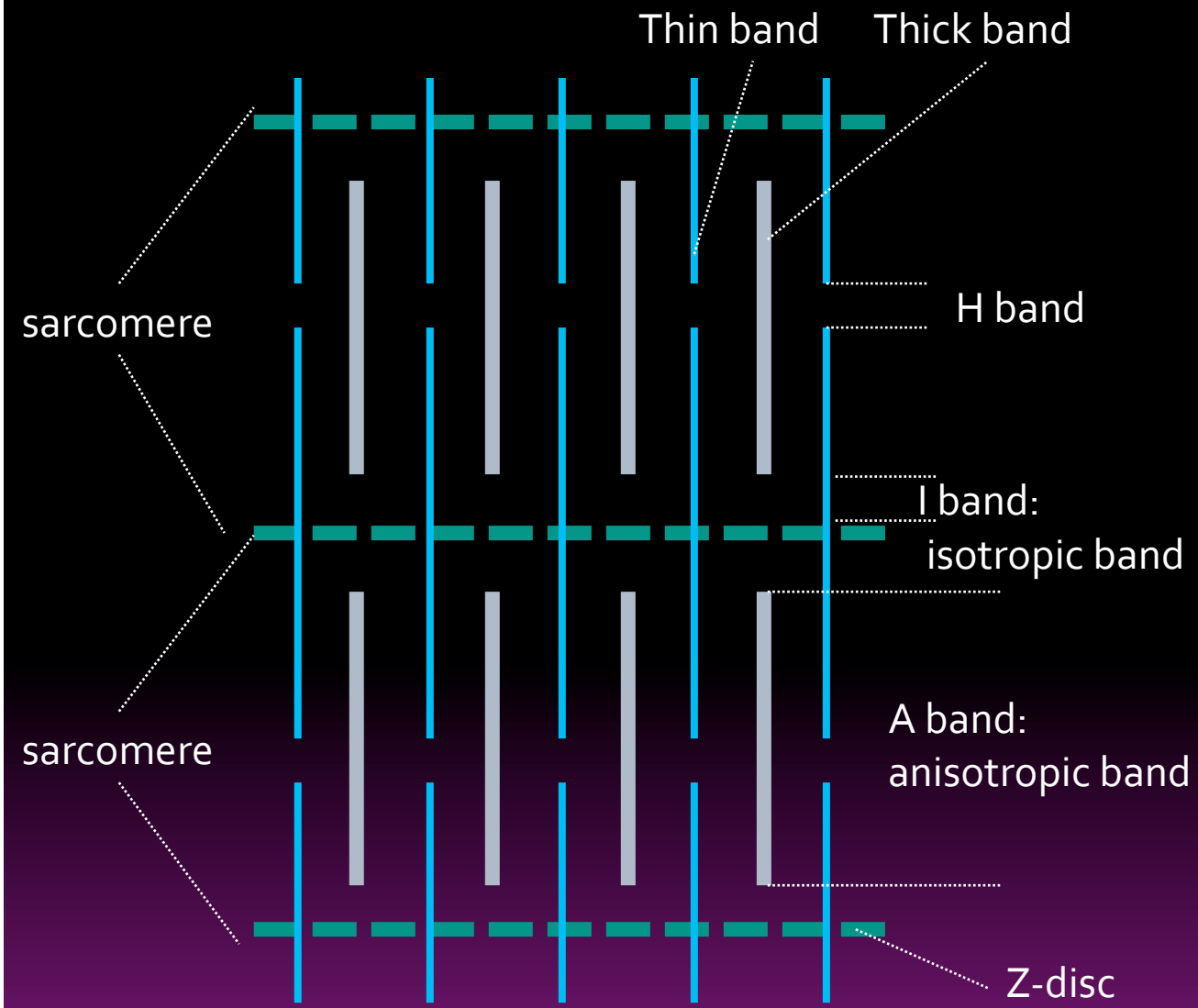


Myosin chains contain many myosin proteins, which are long structures with two heads at one end, making it a directional chain

Other proteins operating in this system include paramyosin, which could form the core of the myosin fibers, tropomyosin and troponin, involved in contraction, and flightin, involved in the asynchronous flight muscles of *Drosophila*

Actin molecules are arranged as two filaments of actin molecules twisted around each other, with a main attachment point at what is called the Z-line or Z-disc

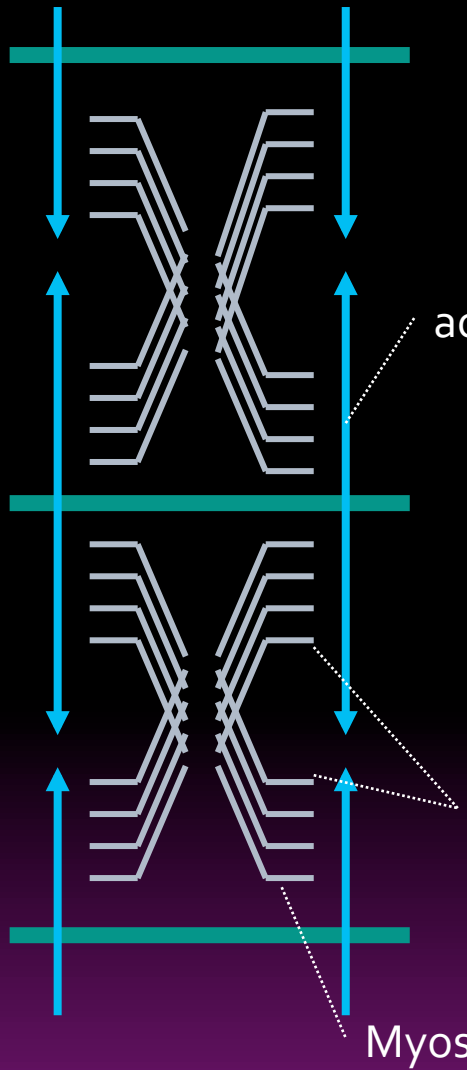
Insect muscles



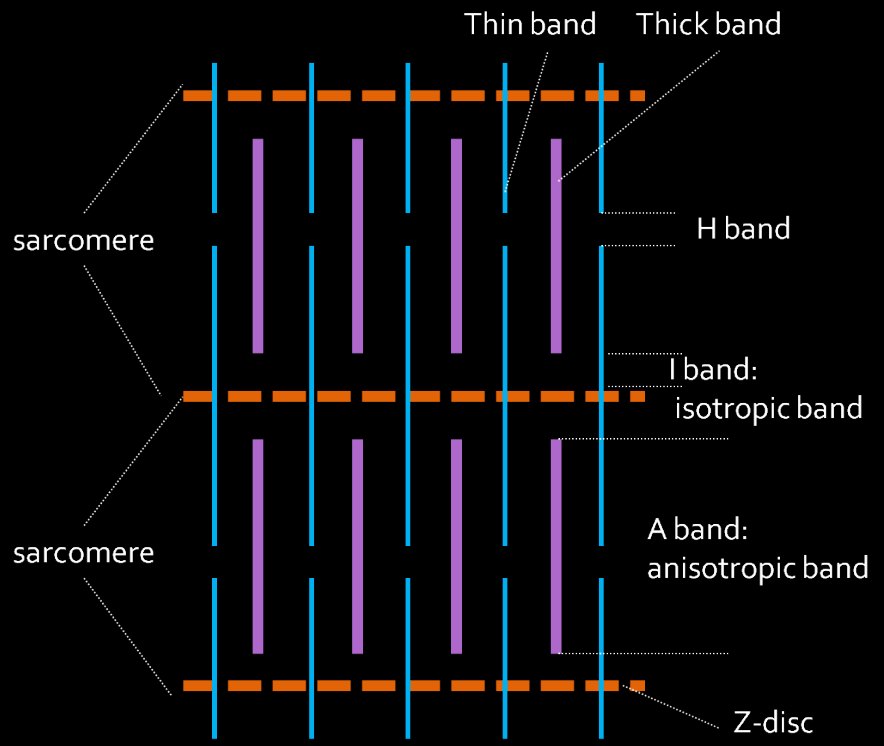
Adapted from Chapman (1998)

- In this diagram of the layout of the different components of a muscle fiber, the thick band is the myosin, the thin bands are the actin components, and the I and A areas indicated are the lighter areas without myosin.
- The H band is the area between the actin filaments, and the Z-disc is the area where the actin filaments form joints

Insect muscles



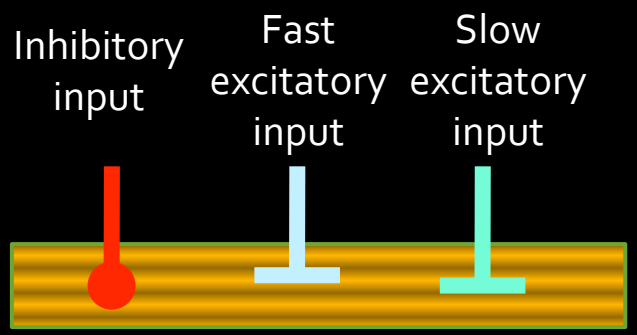
Adapted from Chapman (1998)



Adapted from Chapman (1998)

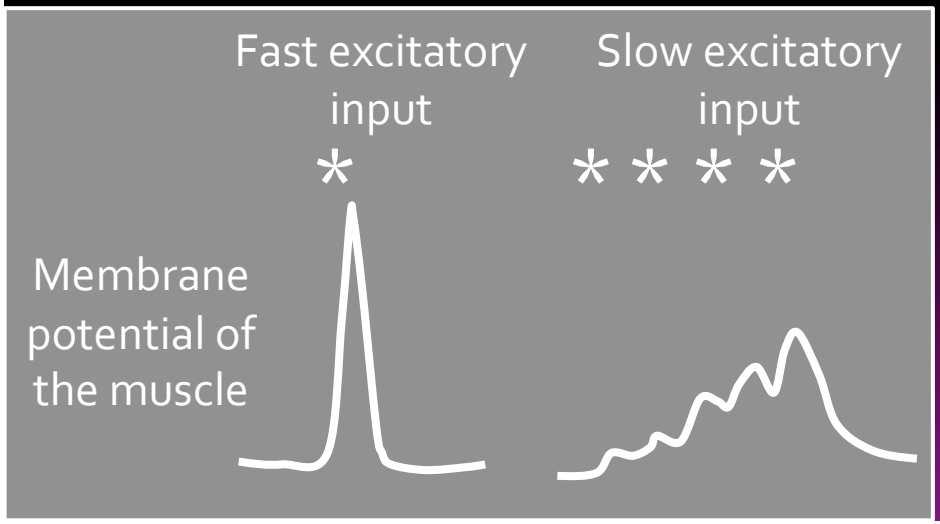
- The myosin molecules are arranged in such a way that the heads are outward toward the Z-disc, with the rest of the molecules going to the inward area of the sarcomere
- The actin filaments also extend to the middle of the sarcomere, but do not touch.

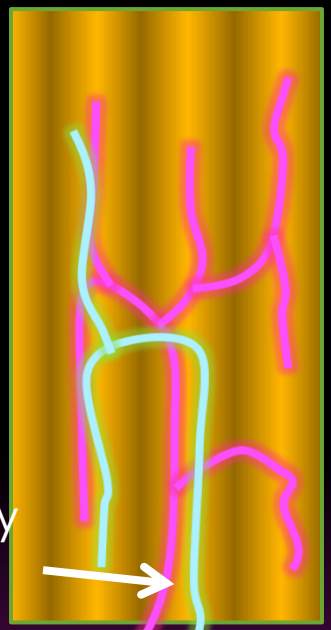
Insect muscles and innervation



- Muscles are innervated by neurons from the central nervous system.
- Insect muscles can get both fast and slow excitatory input as well as inhibitory input
- The different muscle fibers in one muscle can be innervated by the different types of input

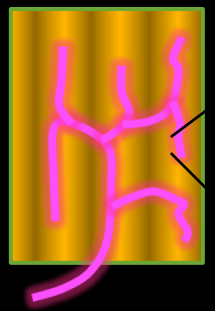
- The difference between the slow and fast inputs is that the fast input can produce a massive change in the electrical activity (or membrane potential) of the muscle fibers while the slow input requires multiple inputs (indicated by a *)



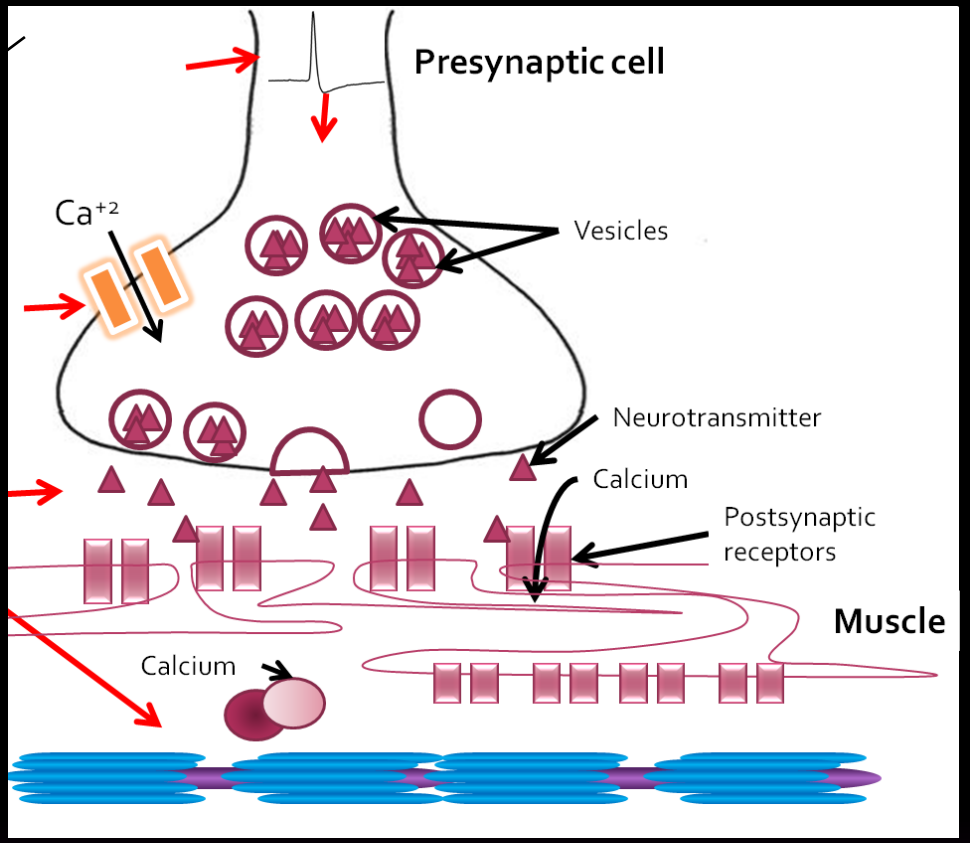


Adapted from Chapman (1998)

Insect muscles: how they are activated



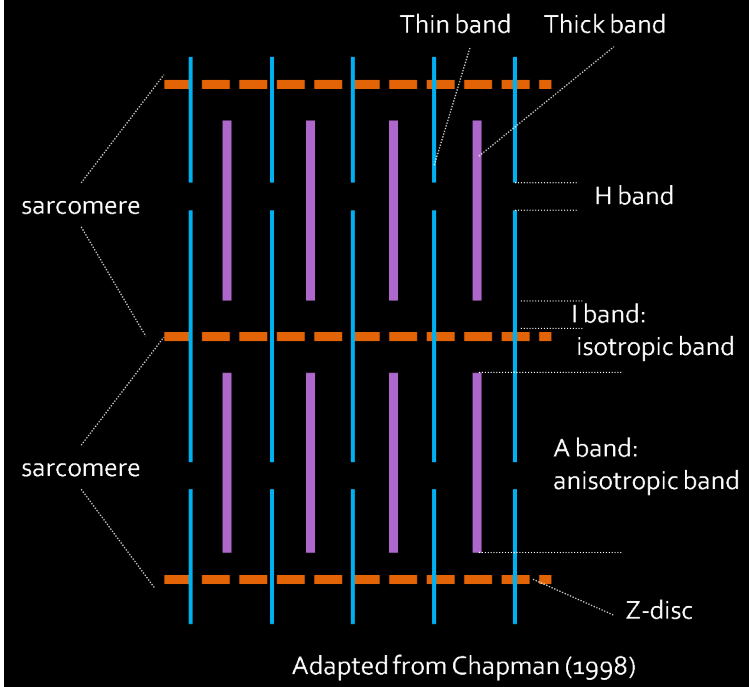
1) Spikes coming from the motor neuron causes the release of glutamate (excitatory) or GABA (inhibitory) neurotransmitter at the neuromuscular junction (NMJ)
2) With excitation, calcium enters the muscle fibers and binds to the protein troponin, which then changes its configuration, allowing its binding partner, tropomyosin, to change its configuration as well.
3) This change then opens the binding site for the myosin heads to link to actin.
4) ATP then allows the myosin to be released from the actin.
5) The cycle of calcium binding and unbinding (through the active removal of calcium, allows the muscle to contract and twitch.



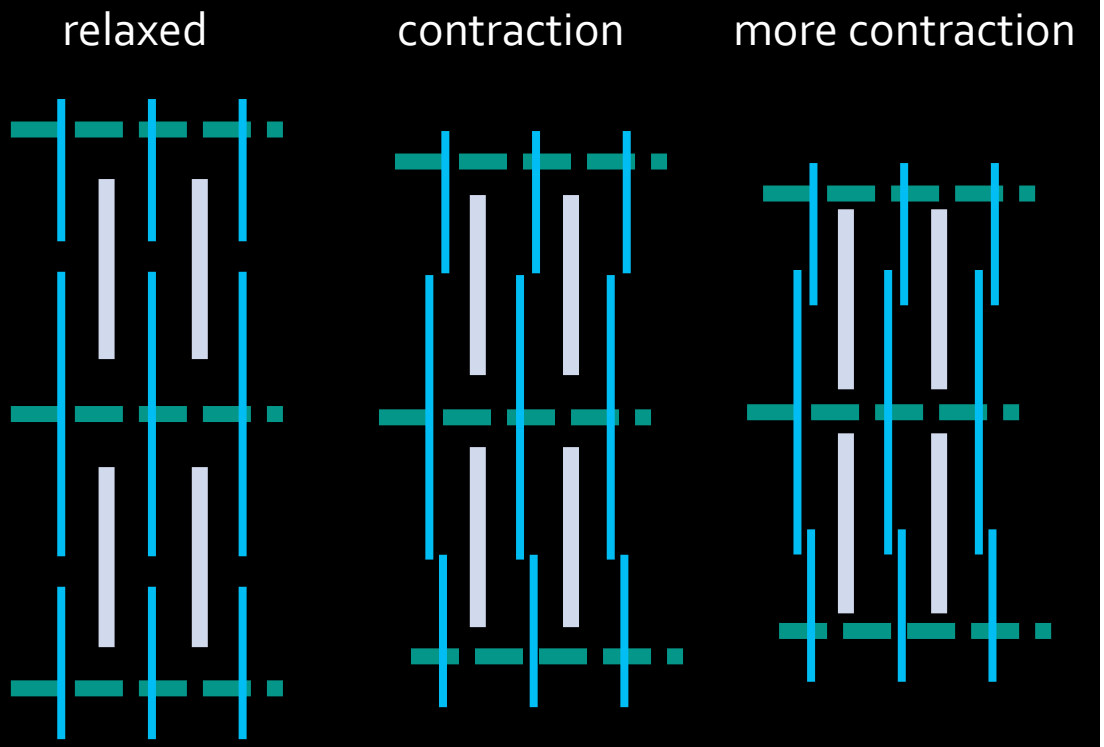
T-system, or the transverse tubular system: invaginations in the muscle fiber allowing the fast binding of neurotransmitter to the ion channels

Extensive sarcoplasmic reticulum invaginations (a part of the endoplasmic reticulum of the cell) also allows for rapid release and uptake of calcium

Insect muscles



Adapted from Chapman (1998)



Adapted from Chapman (1998)

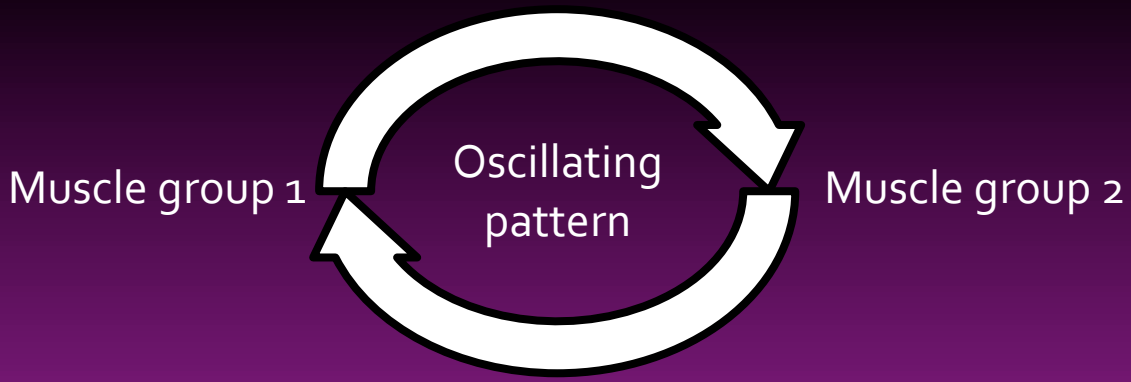
The binding and unbinding of the myosin and actin can cause the actin fibers to overlap with more and more contraction.

The well-developed sarcoplasmic reticulum of the muscle fibers allow fast release and sequestering of calcium

In the process, the shifting and binding of the different proteins can draw the Z-discs together, causing more or less contraction

Antagonistic muscles and oscillations

- At most joints, there are antagonistic muscle pairs which cause the extension or retraction of a joint or alternate between one side or the other
- To move, such as in locomotion and in the case of flight muscles, movement is caused by an oscillation of contractions of one muscle group versus another over time.
- By oscillating back and forth, particularly in flight or walking, the limbs can move in a rhythmic manner.
- This can be coordinated in the nervous system, where the neurons produce a rhythmic pattern of excitation and inhibition producing contraction and relaxation in the muscles
- Also, in the asynchronous muscles (as in many flying insects), the increase in tension in one muscle group (dorsoventral muscles) can cause the other antagonistic muscle group (dorsal longitudinal muscles) to be extended (because of the mechanics of the thorax), thereby increasing tension the dorsal longitudinal muscles, which then begin to contract, and stretch the dorsoventral muscles, causing the circuit to oscillate



Insect muscles

Adapted from Chapman (1998)

- Synchronous muscle groups require constant direct stimulation from the nervous system to contract
- Asynchronous muscle groups only require a few neural inputs to initiate contraction and to maintain, but the muscles can oscillate long after the time point of neural input