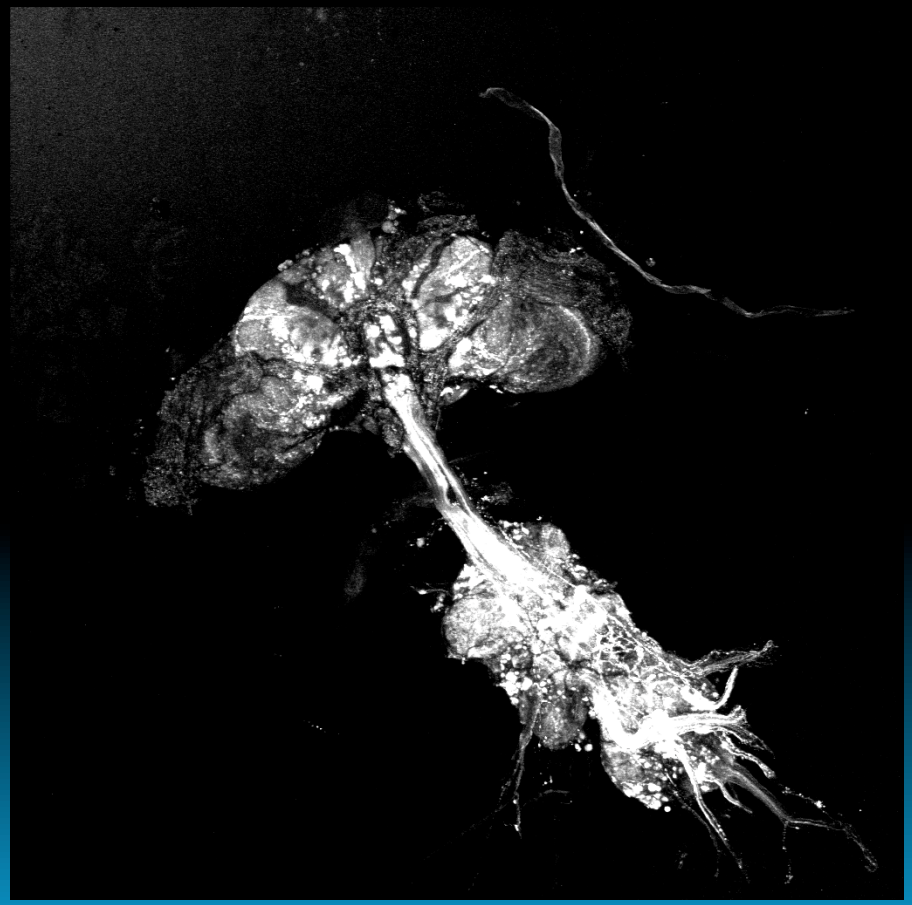
THE NERVOUS SYSTEM: HOW IT ALL COMES TOGETHER

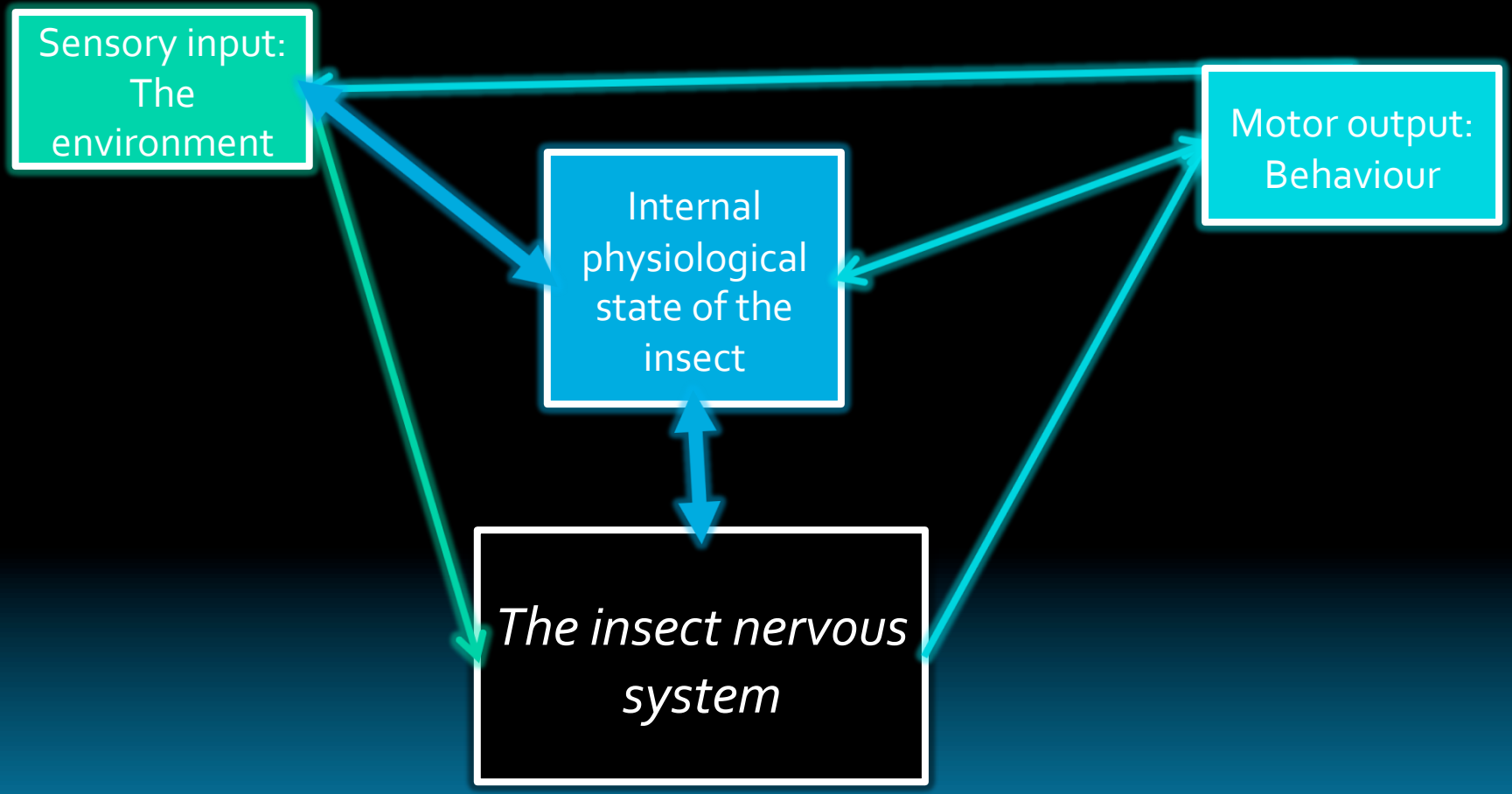


Angelique Paulk

Objectives

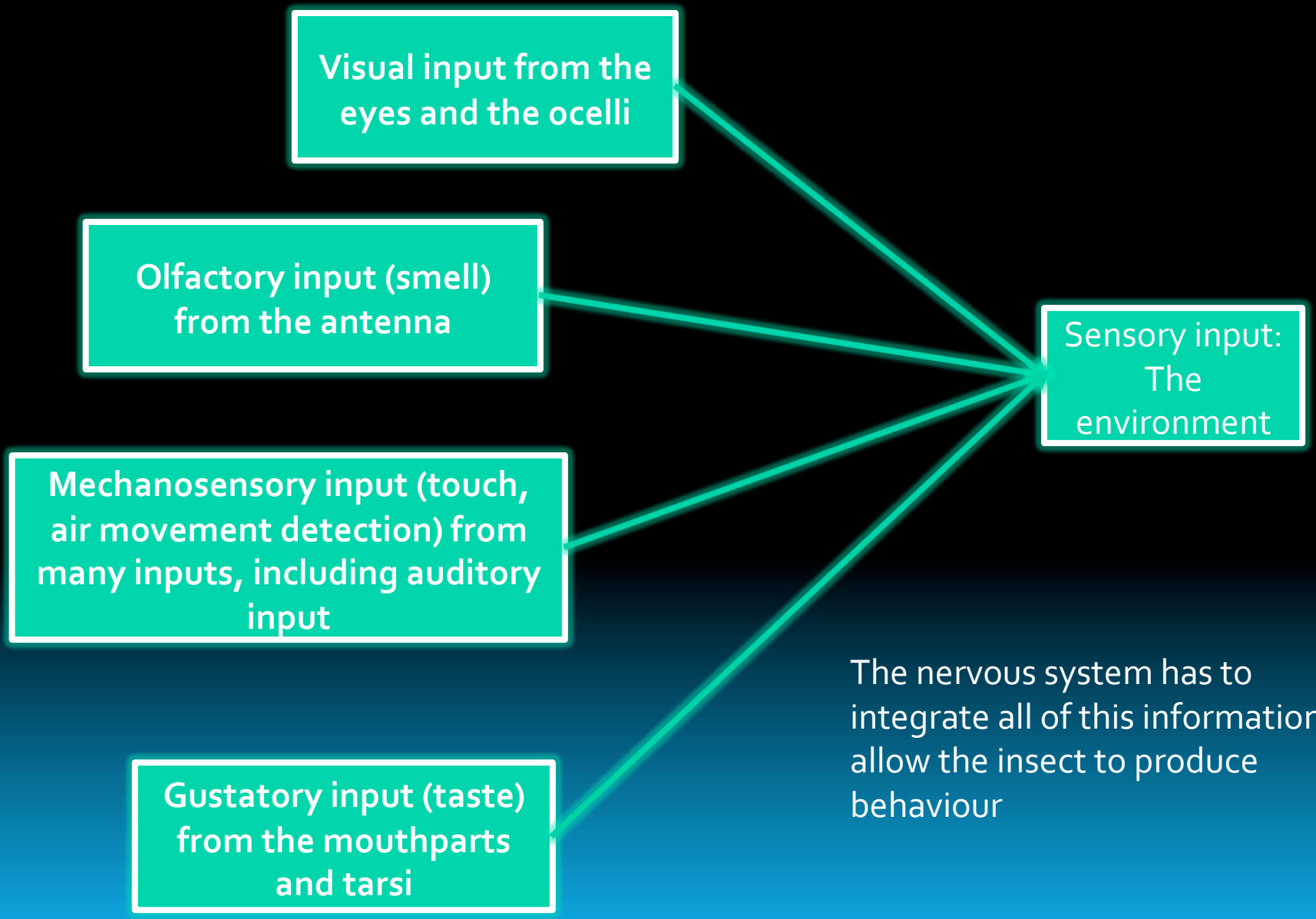
- What is the basic layout of the nervous system?
- How is it all integrated?
- Understanding how the nervous system can integrate everything

The ‘black box’



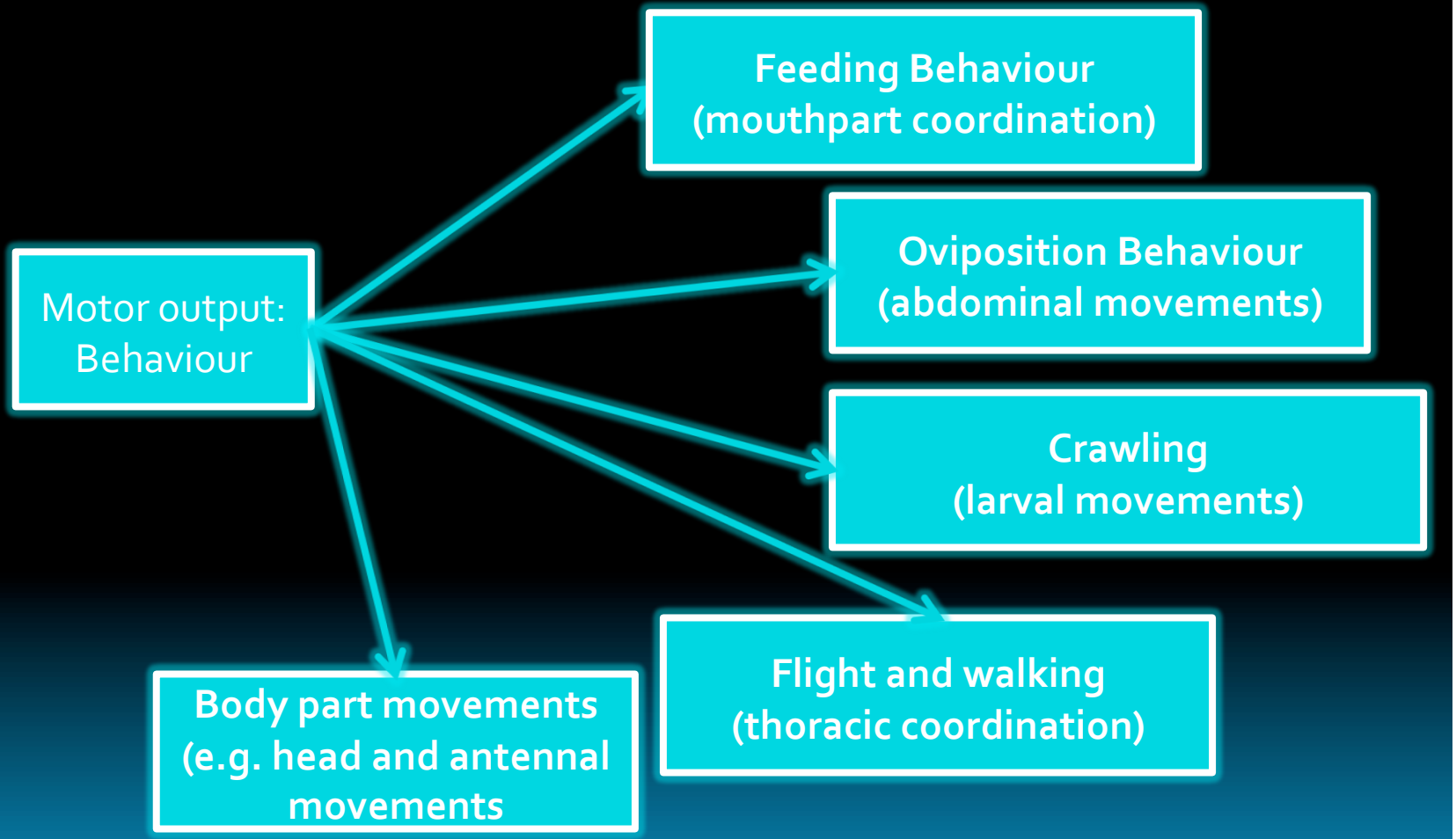
Considering the numerous connections between the sensory input, the motor output, and the internal physiological state: How do we unravel the mechanisms in the ‘black box’ of the insect nervous system?

Sensory input: the different types



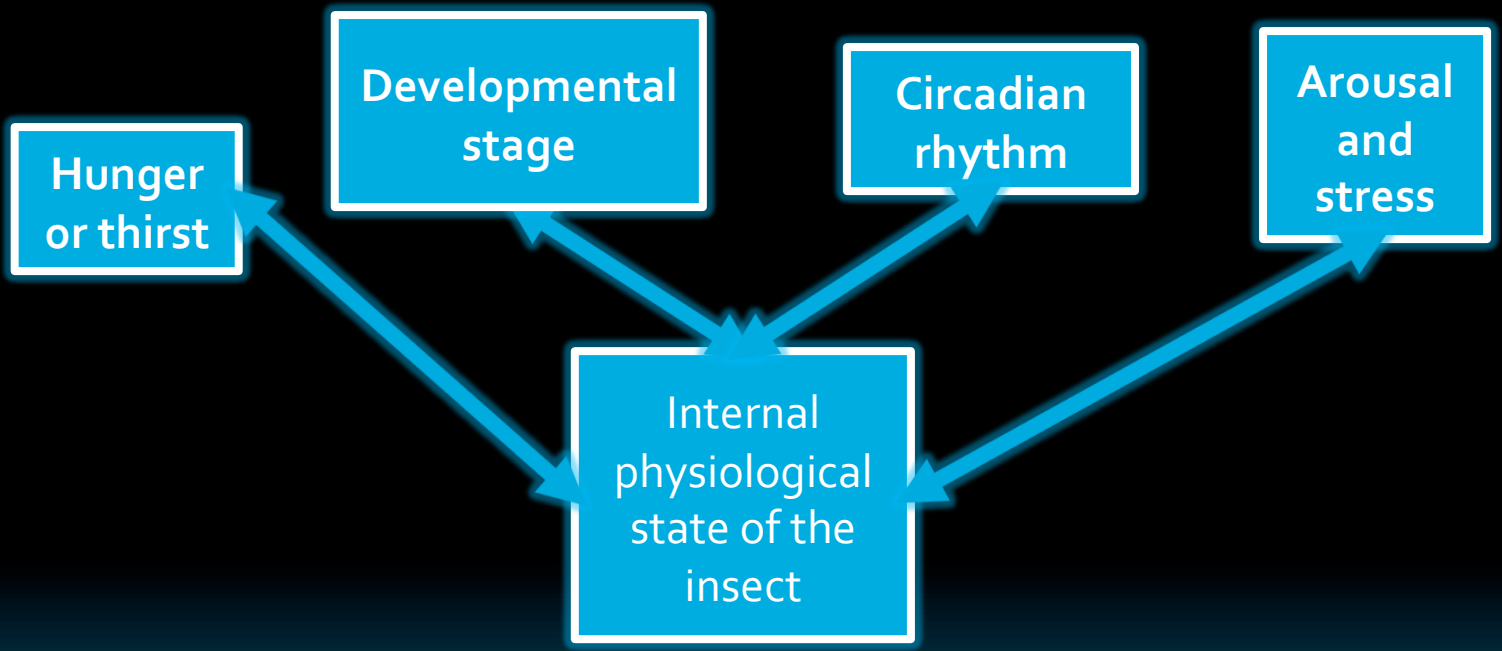
The nervous system has to integrate all of this information to allow the insect to produce behaviour

Motor output: where behaviour is produced



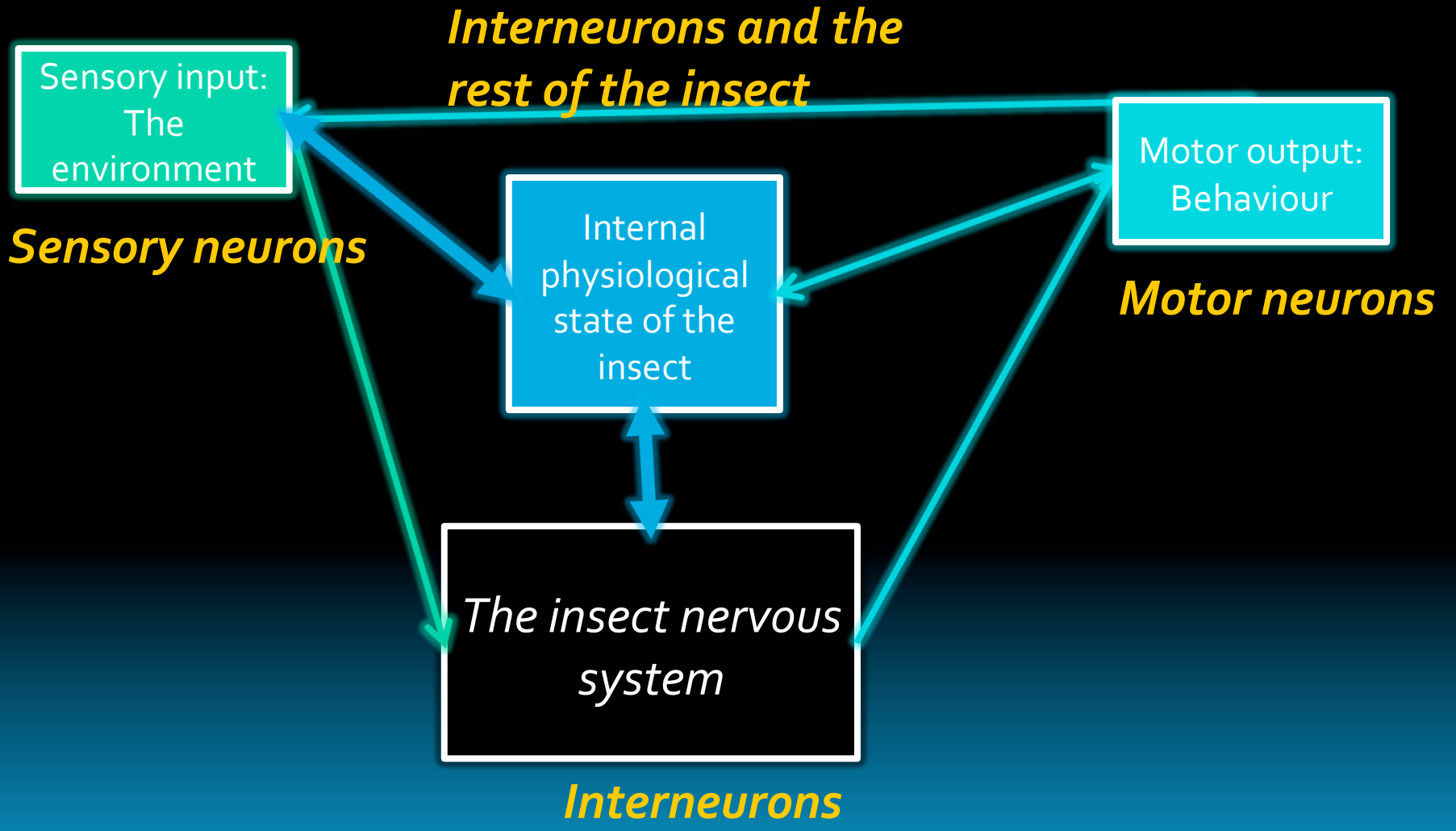
The motor output can produce a variety of different types of behavior depending on the sensory input and the physiological state of the animal

Internal physiological state



In addition to the sensory input and the motor output, the physiological state of the insect can play a major role in how the nervous system works

The ‘black box’



How is the nervous system wired?

The insect nervous system

- The insect nervous system is composed of a series of bundles of nerve fibers, called ganglia, which are composed of brain cells, or *neurons*.
- Evolutionarily, a fusion of many of these ganglia led to the formation of the brain, located in the head, and enlarged thoracic ganglia (reference)

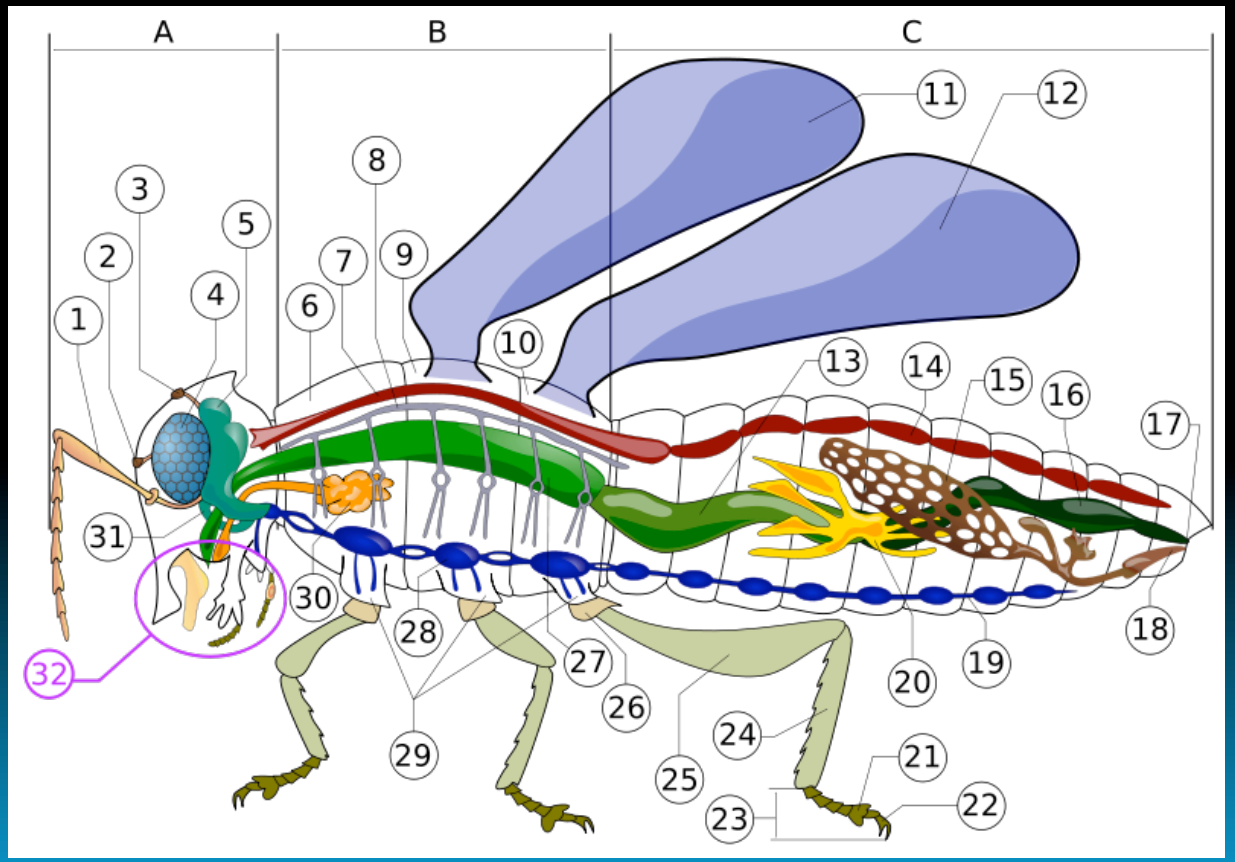
- The basal condition in the insect nervous system is:
  1. A brain
  2. The subesophageal ganglion
  3. Three thoracic ganglia (called the prothroacic, mesothoracic, and metathoracic ganglia)
  4. A chain of abdominal ganglia

All of these structures are connected by nerves called connectives

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)



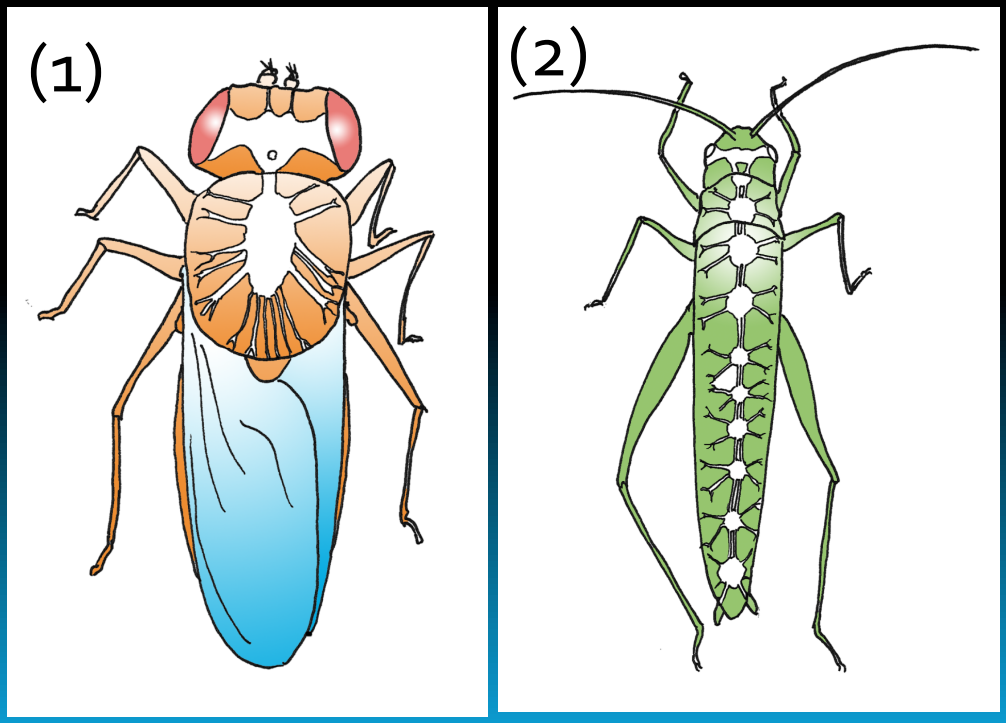
A. Head
B. Thorax
C. Abdomen

Piotr Jaworski, PioM, Wikipedia Commons

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

The insect nervous system: different designs

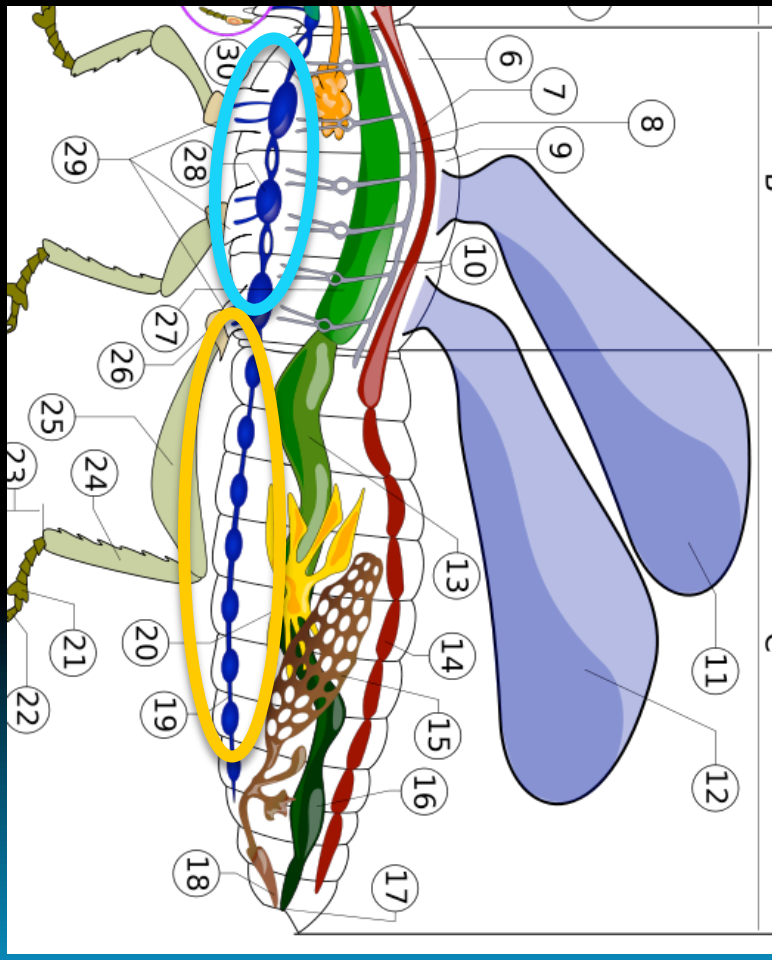
Like any system in insects, there have been various modifications to this design, which includes fusion of all the ganglia (1) to clear separation of the ganglia (2) (which is the basal condition)



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



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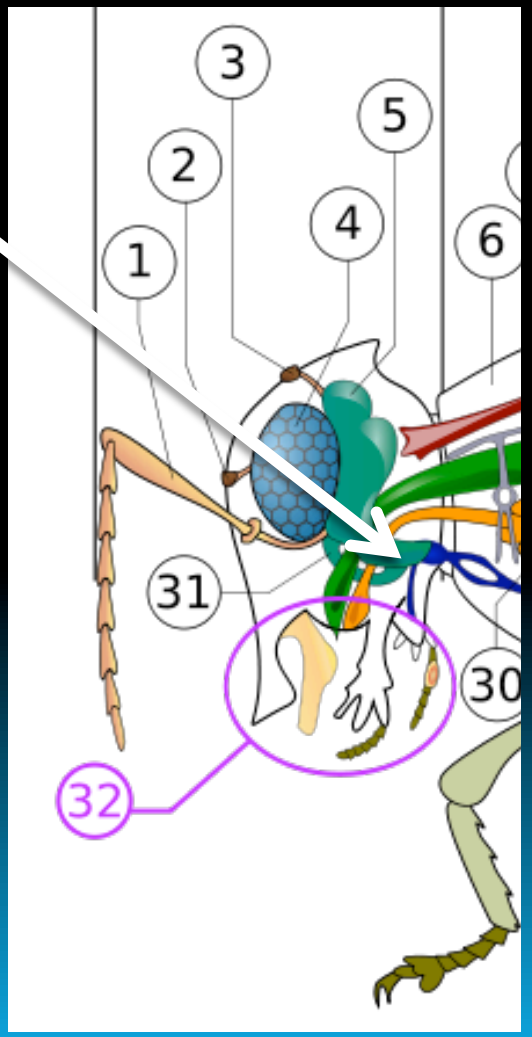
Within the nervous system: the subesophageal ganglion

- The subesophageal ganglion is closely associated with the brain and lies underneath the gut .
- The brain is then connected via nerves to wrapping around the gut, with the brain above (dorsal to) the gut
- The subesophageal ganglion contains key structures for neurohormones and is a major interface between the rest of the body and the brain.



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Within the nervous system: the brain

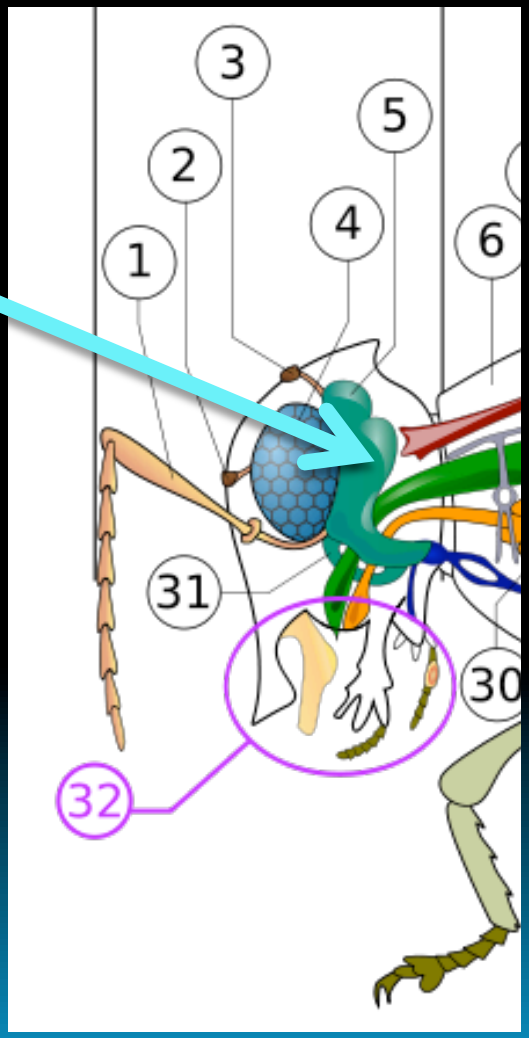
The brain has a large amount of sensory input from the eyes, the antenna, the mouthparts, and input from the thoracic ganglion via the cervical connective

The brain is one of the major integrators of information in insects.

However, if you cut it off, many insects can live for days.

Why? Because the thoracic and subesophageal ganglia contain the motor centers and much of the circuitry for living, except for feeding.

In other words, the insect has two brains: the 'brain' and the thoracic ganglia!



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

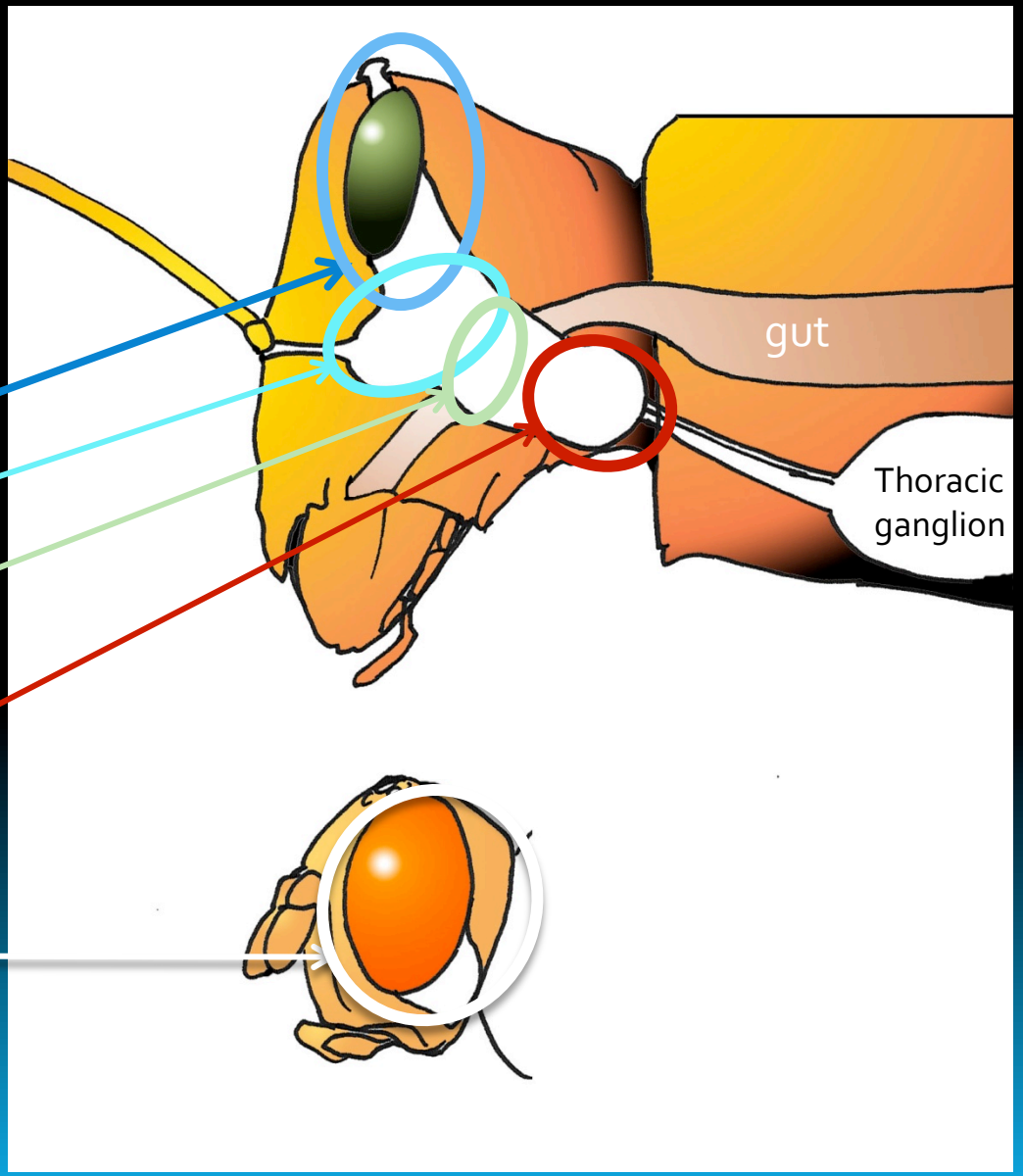
Within the nervous system: the brain

The brain (white) is divided into three major regions.

The brain is divided into:

1. Protocerebrum
2. Deutocerebrum
3. Tritocerebrum
4. Subesophageal ganglion

The protocerebrum, deutocerebrum, tritocerebrum, and subesophageal ganglia are relatively fused in many insects



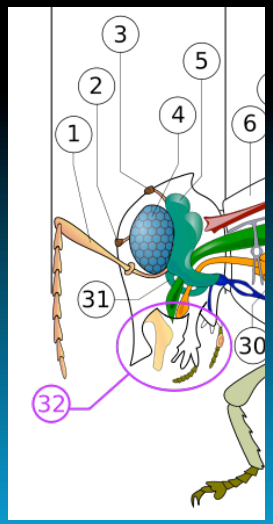
Within the nervous system: the brain

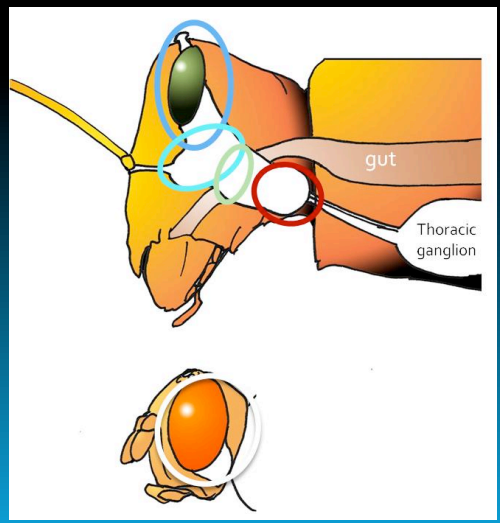
The functions and brain areas involved are:

1. **Protocerebrum**: visual input from the eyes and the ocelli, pars intercerebralis, and major central brain structures called the ***mushroom bodies*** and ***central complex*,** which are discussed in another mini-lecture.

2. **Deutocerebrum**: Antennal inputs and processing area (olfaction and mechanosensation) and antennal motor center

3. **Tritocerebrum**: nerve connections to the labrum of the insect and gustatory inputs





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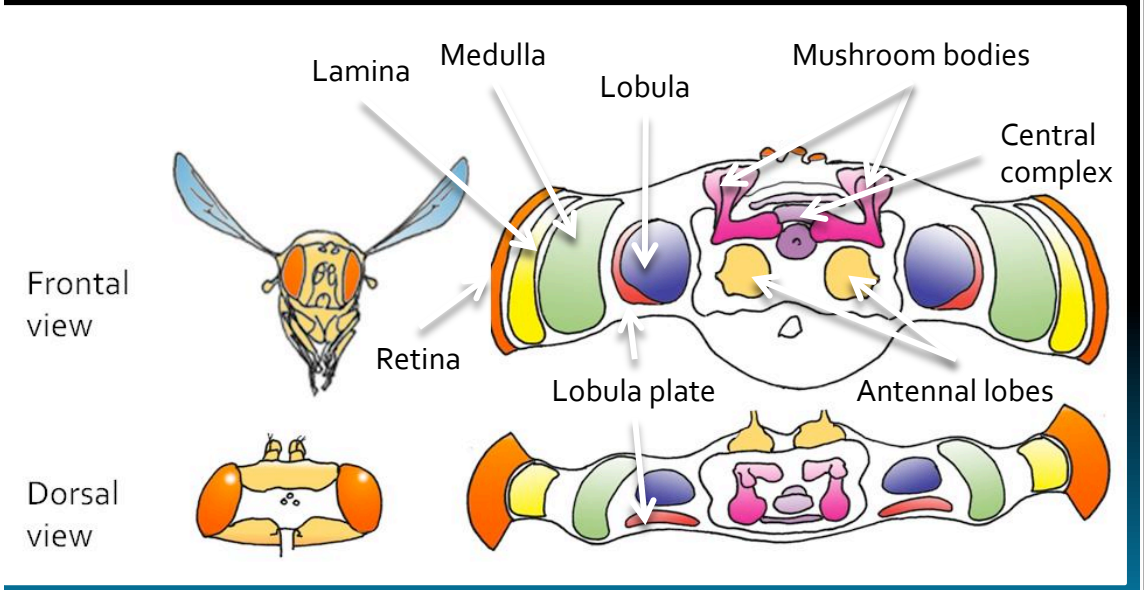
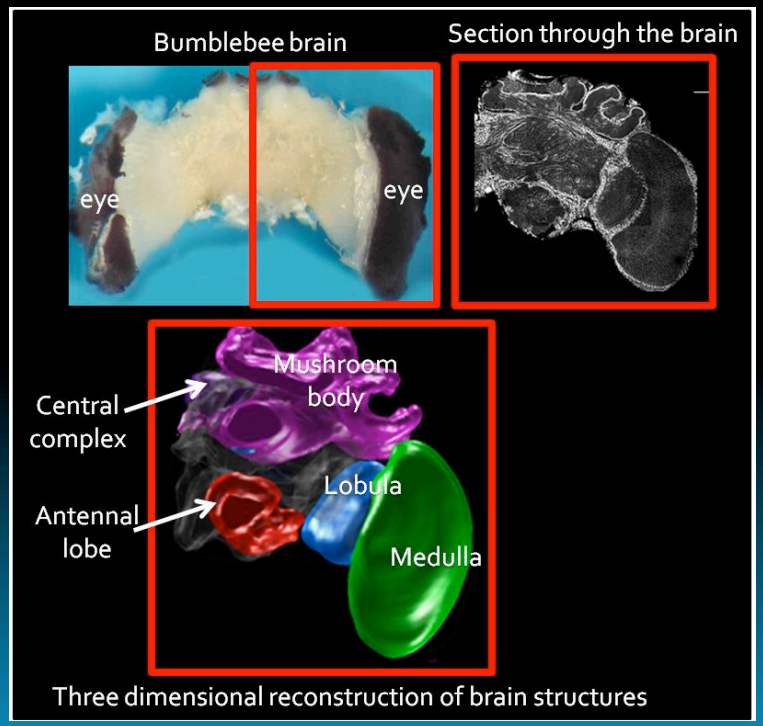
The nervous system: layout and function

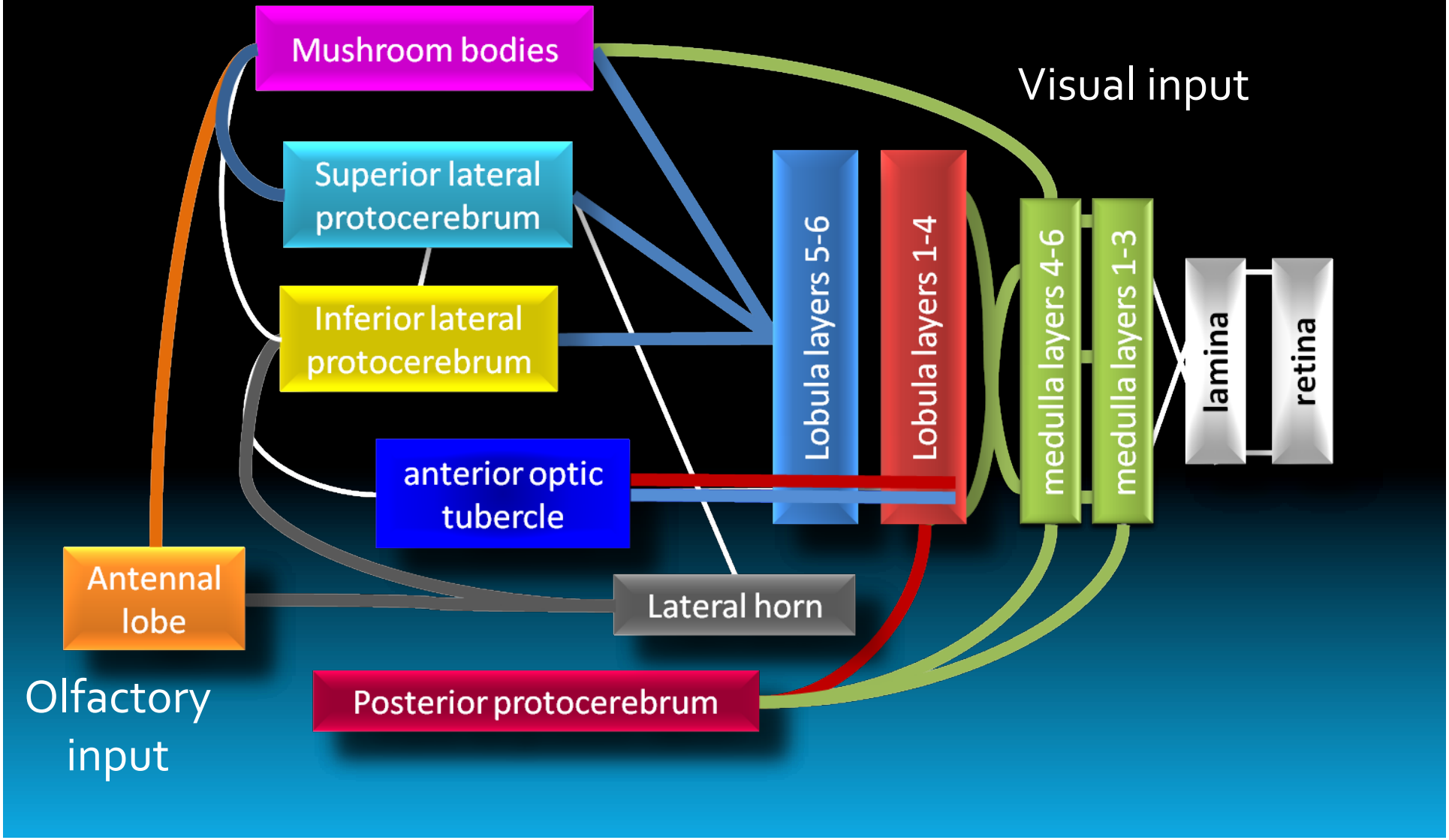
The insect nervous system contains numerous inputs and outputs, though their wiring and connectivity depend on the functional role of the circuit.





Integration into the rest of the system

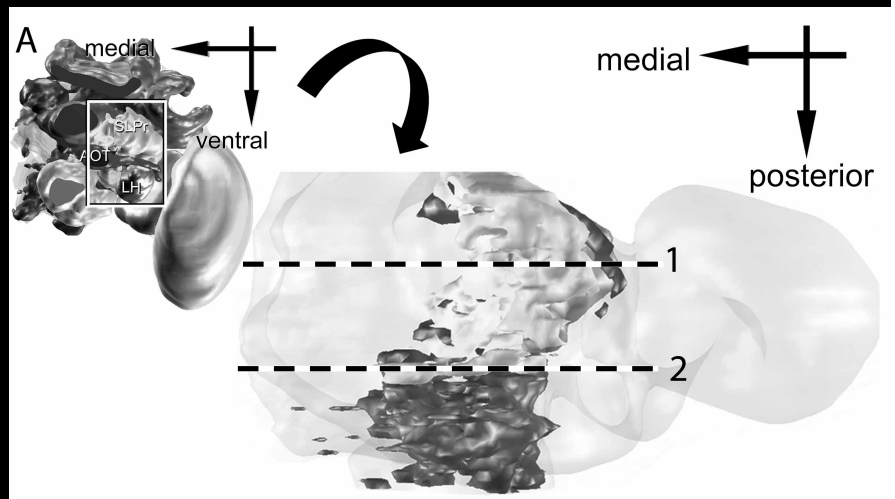
The visual system, of course, then inputs to the central brain, with numerous connections throughout the circuit

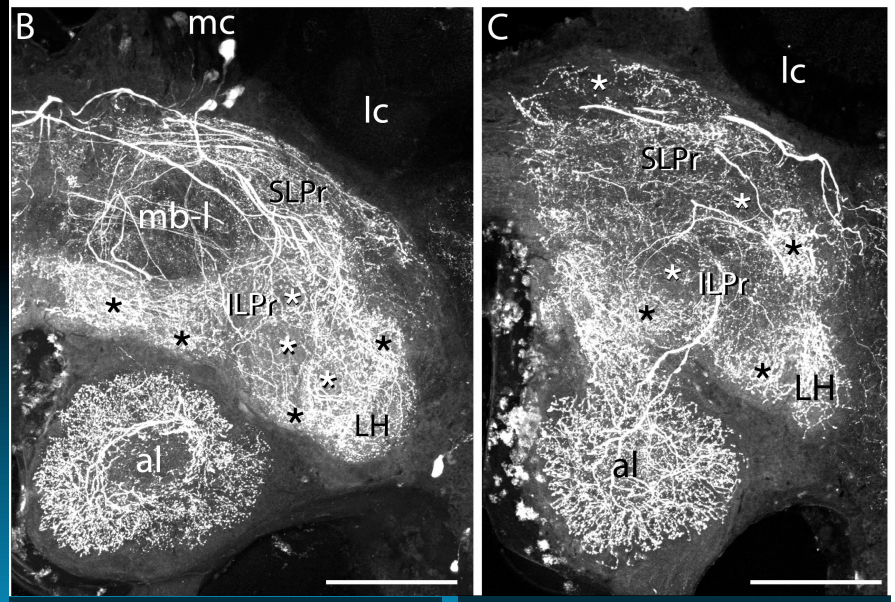


Neuromodulatory input is distributed throughout the brain

- Neuromodulatory input is differentially distributed throughout the brain
- Neuromodulatory input can indicate the arousal state of the insect (such as octopamine) or correlate with the circadian rhythm (such as serotonin)

Neobellieria bullata brain, serotonin staining





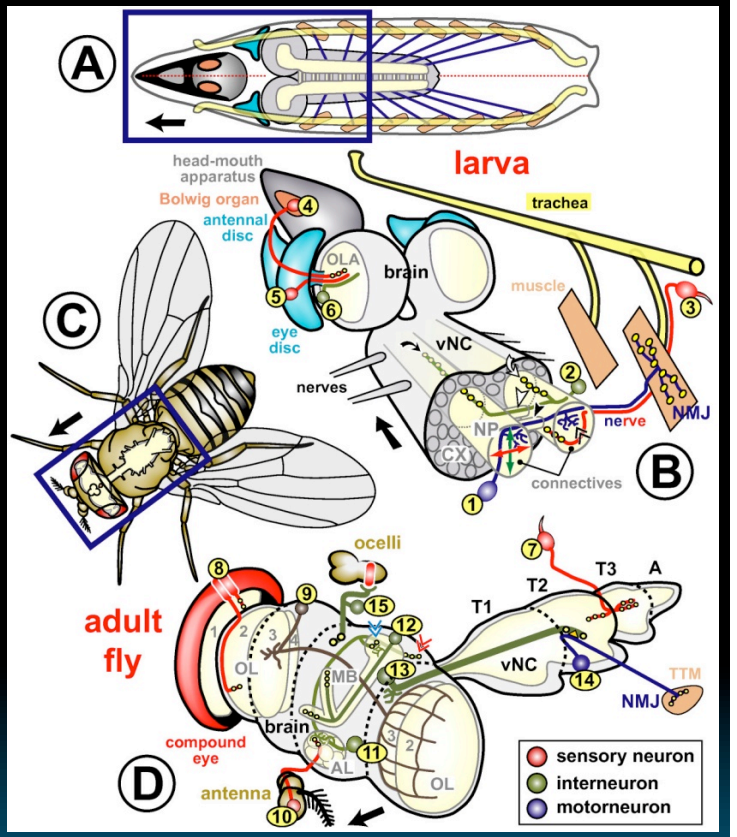
Bombus impatiens brain, serotonin staining

Bombus impatiens brain, histamine staining

The nervous system

The insect system is even more complicated than these basic connection schemes
Check out the following websites which display the layout of the fly brain (1), the *Drosophila* adult and larval brains (2), and the layout of the honeybee brain (3):

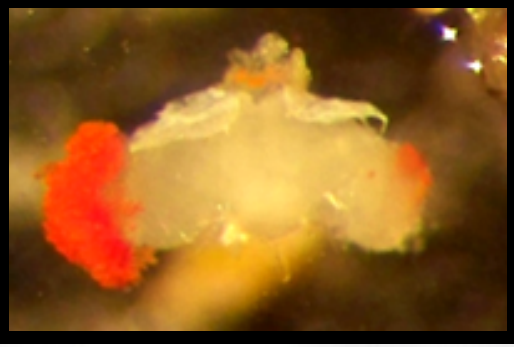
1) http://flybrain.neurobio.arizona.edu/
2) http://www.neuraldevelopment.com/content/2/1/9
3) http://www.neurobiologie.fu-berlin.de/beebrain/Default.html

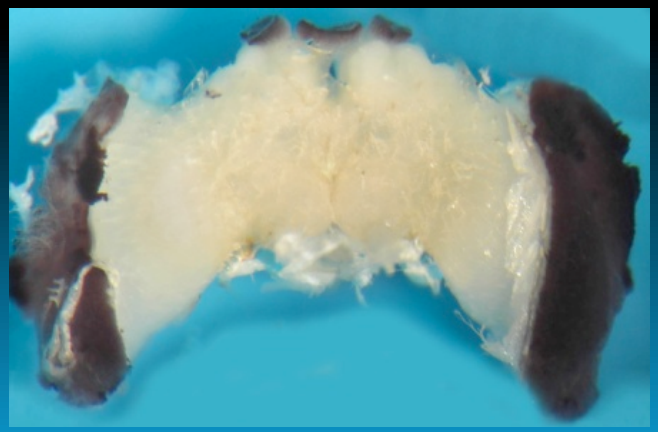


Sánchez-Soriano N, Tear G, Whitington P, Prokop A. Wikipedia Commons

http://commons.wikimedia.org/wiki/File:Neurons_used_for_studies_on_neuronal_growth_at_different_stages_of_Drosophila_development.jpg

The brain can come in many different sizes, but similarities remain





André Karwath aka Aka, Wikipedia Commons