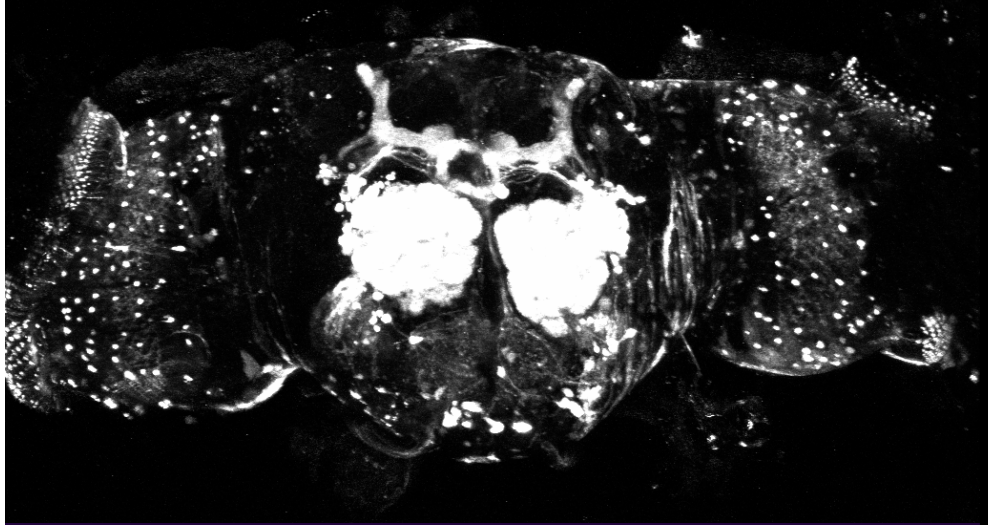
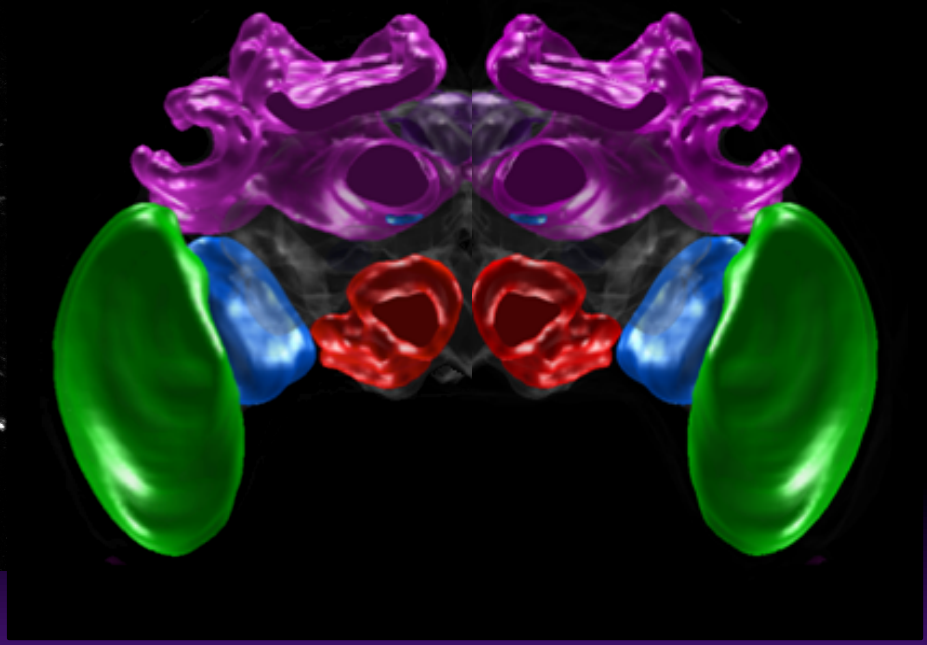
MEMORY, LEARNING, AND THE INSECT BRAIN





Angelique Paulk

COMMONWEALTH OF AUSTRALIA
Copyright Regulations 1969

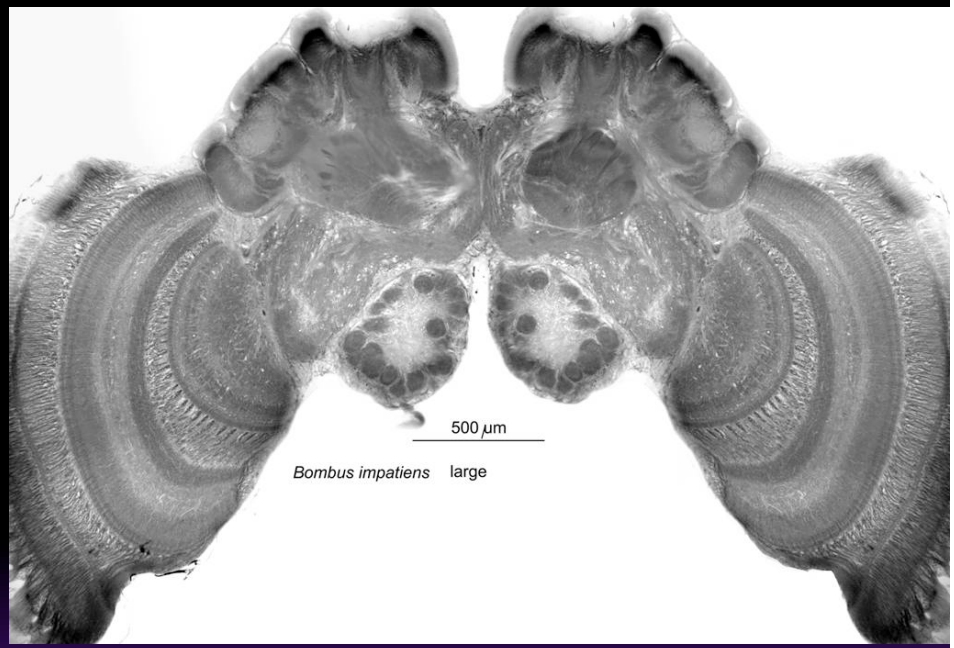
WARNING
This material has been reproduced and communicated to you by or on behalf of the University of Queensland pursuant to Part VB of the Copyright Act 1968 (the Act).

The material in this communication may be subject to copyright under the Act. Any further reproduction or communication of this material by you may be the subject of copyright protection under the Act.

Do not remove this notice.

Objectives

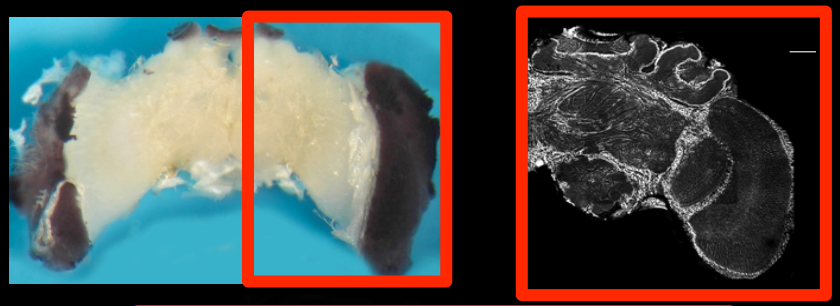
- How does learning and memory operate at the neural level?
- What brain areas do what in terms of learning and memory?



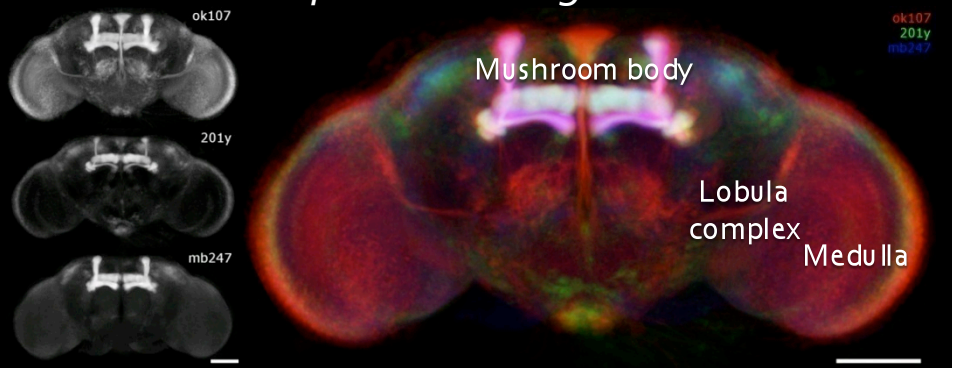
Learning and memory: involves changes in the connections between cells

- Memory and changes in synaptic strength can occur at many different levels of the insect brain

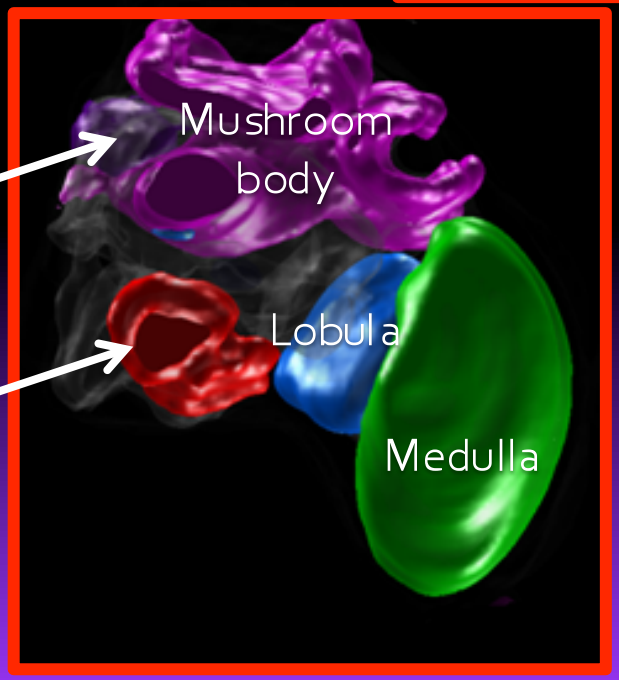
Bumblebee (*Bombus impatiens*)



Drosophila melanogaster



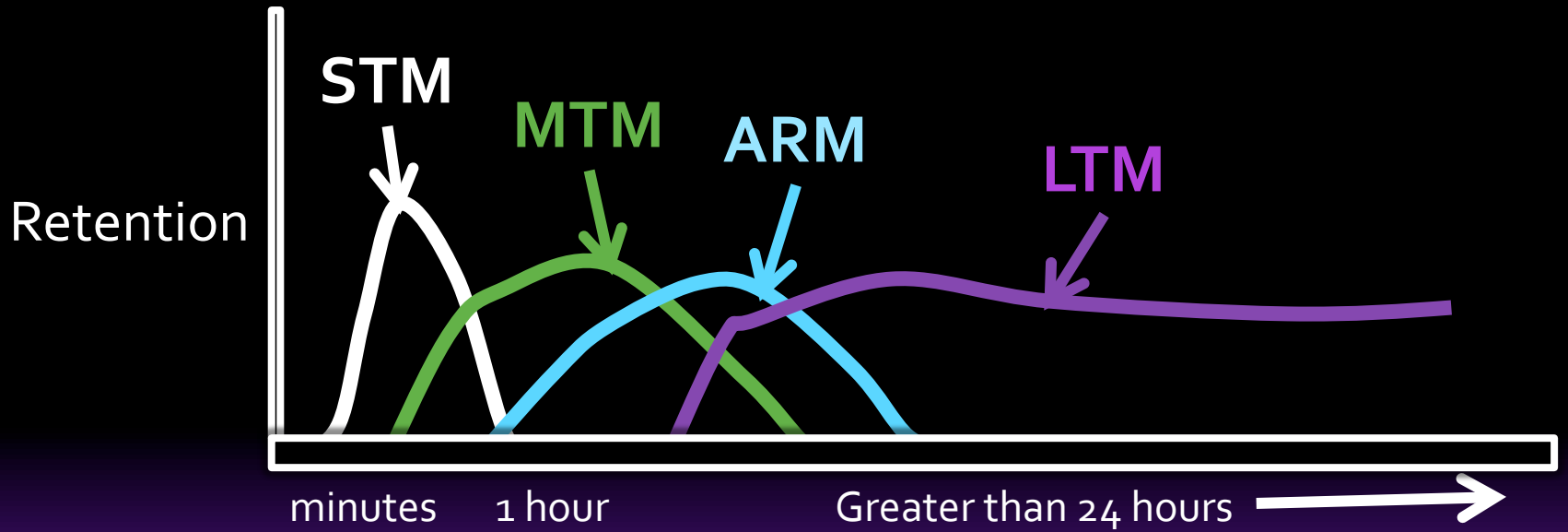
Jenett A, Schindelin JE, Heisenberg M. Wikipedia Common



- Memory and changes in synaptic strength can occur at many different levels of the insect brain
- Prominent areas where learning and memory have been shown to occur are:
  - Antennal lobes
  - Mushroom bodies
  - Central complex

Learning and memory: Different types of memory

- Short-term (STM), middle-term (MTM), anesthesia resistant (ARM), and long-term (LTM) memory can induce different levels of changes in the connections between cells



Short term synaptic changes: Facilitation and depression

Mid term synaptic changes: Increase the number of receptors on the postsynaptic cell, or increasing neurotransmitter release

Long term synaptic changes: Change the synapse, add more synapses, permanently increase the synaptic strength, involving protein synthesis

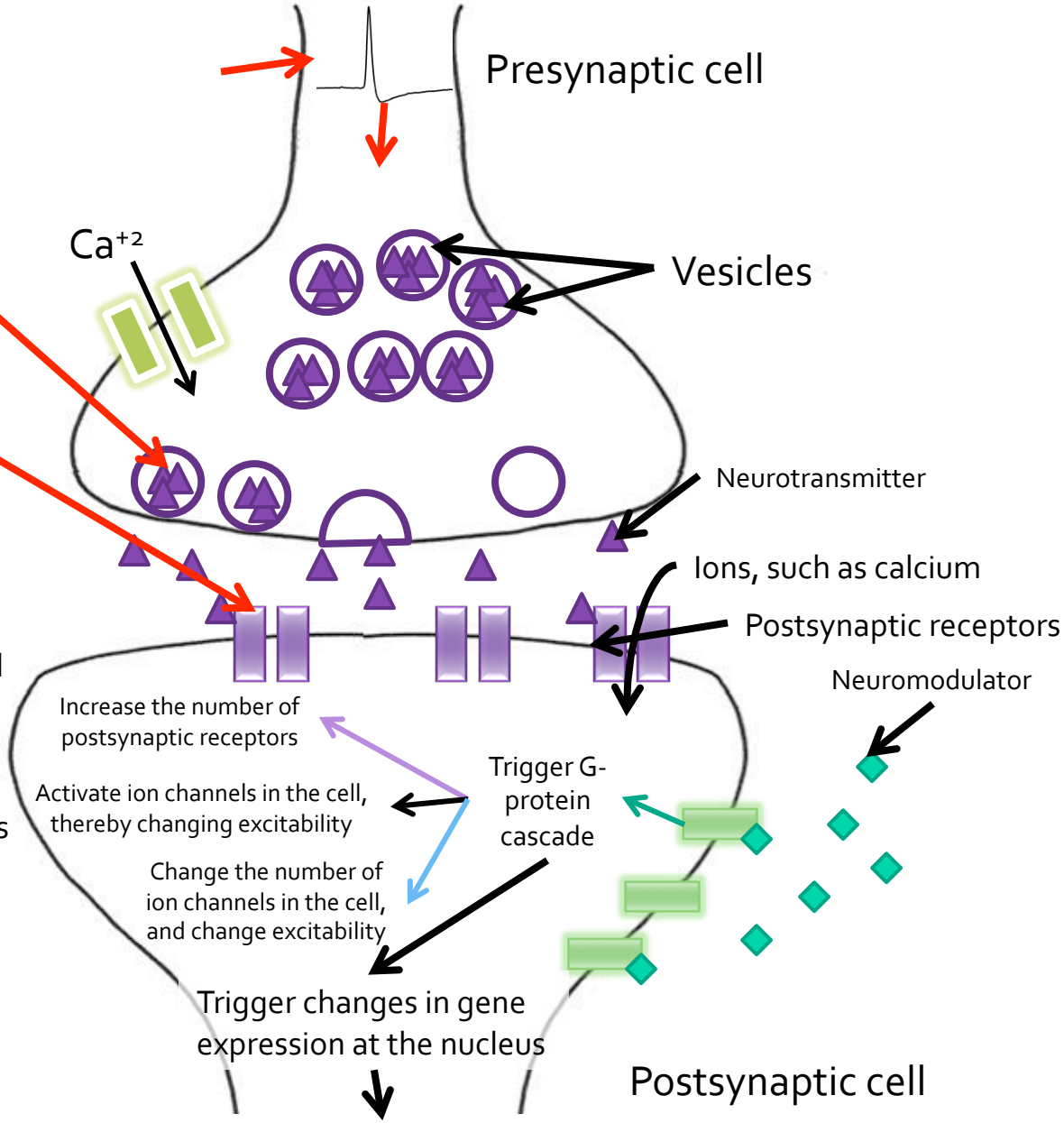
The synapse: How learning can happen

To increase or decrease the strength of a synapse, a series of changes can occur:

1. ***The amount of neurotransmitter released per vesicle can increase or decrease***
2. ***The number of postsynaptic receptors can increase or decrease***
3. ***Cells can also increase or decrease the number of synapses connecting them***

These changes in synaptic strength often involve a series of molecular and protein changes in the cell, which can be triggered by:

1) increasing or decreasing synaptic transmission, particularly in terms of the timing of inputs
2) by the application of neuromodulators like dopamine to trigger molecular pathways in the cell



The synapse: How learning can happen

- Numerous *Drosophila* mutants have been found where changes on the synaptic level have caused the flies themselves to have behavioural defects, such as poor learning and memory

- Much of this information is discussed at this website:
http://en.wikipedia.org/wiki/Drosophila_melanogaster

- Much of the material on *Drosophila* learning and memory is listed at the following book, if you can access it online:
http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=bnchm&part=A3577

- And a number of the genes involved in the *Drosophila* brain are listed here:
http://www.sdbonline.org/fly/brain/ahome.htm

- Another tool researchers use to study Drosophila is borrowed from yeast, called the GAL4-UAS system, which is outlined below:
http://en.wikipedia.org/wiki/GAL4/UAS_system

- Using this system, the certain genes can be turned on and off in specific areas of the brain.

Studying how learning can happen

- Numerous *Drosophila* mutants have been found where changes on the synaptic level have caused the flies themselves to have behavioural defects, such as poor learning and memory

- Much of this information is discussed at this website:
http://en.wikipedia.org/wiki/Drosophila_melanogaster

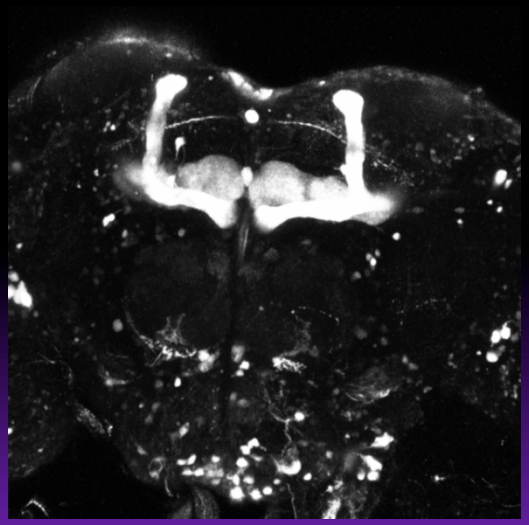
- Much of the material on *Drosophila* learning and memory is listed at the following book, if you can access it online:
http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=bnchm&part=A3577

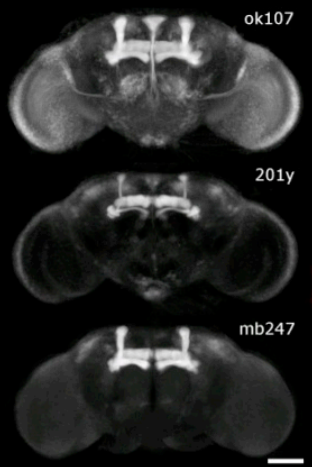
- A list of the genes :
http://www.sdbonline.org/fly/aimain/1aahome.htm

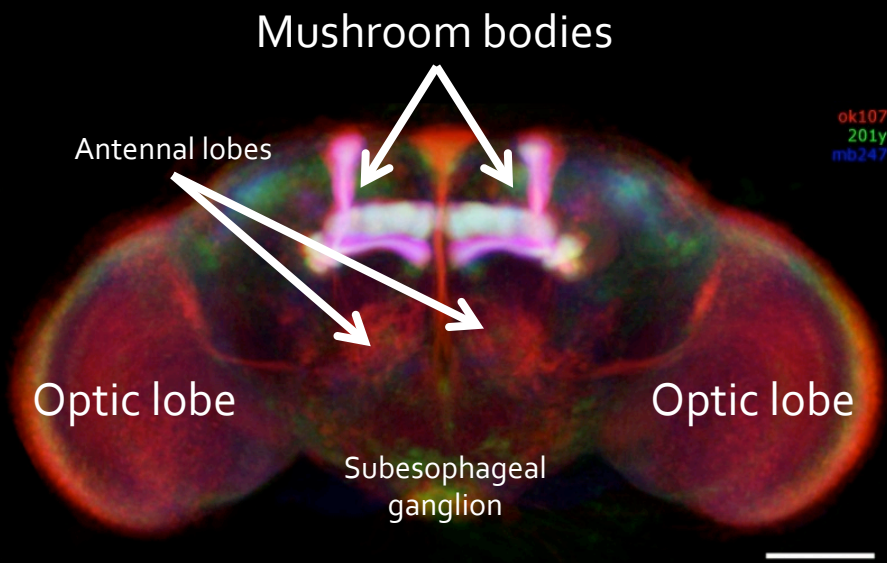
- Using this system, the certain genes can be turned on and off in specific areas of the brain.

Learning and memory: the circuitry of learning

GAL4-UAS expression of green fluorescent protein (GFP) in the mushroom bodies of *Drosophila melanogaster*:





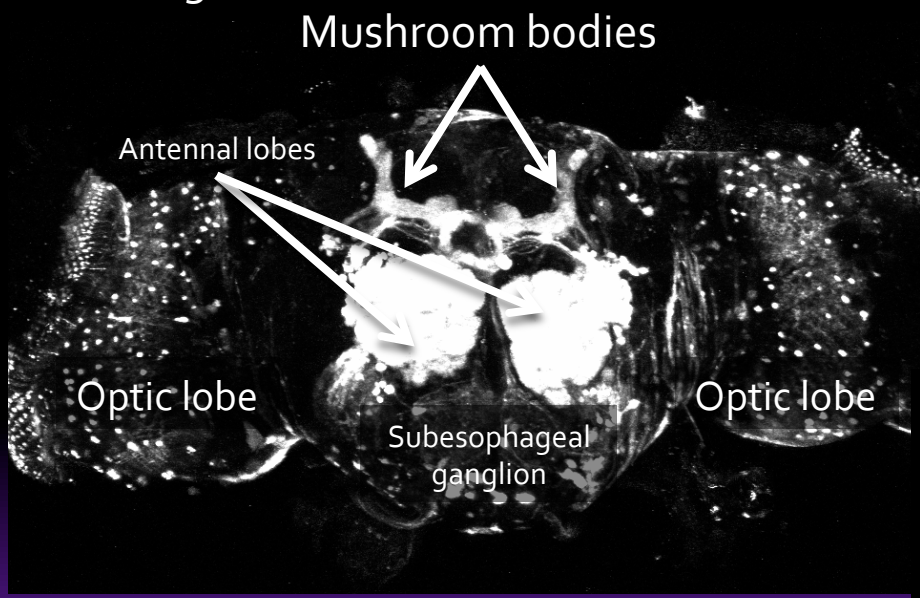


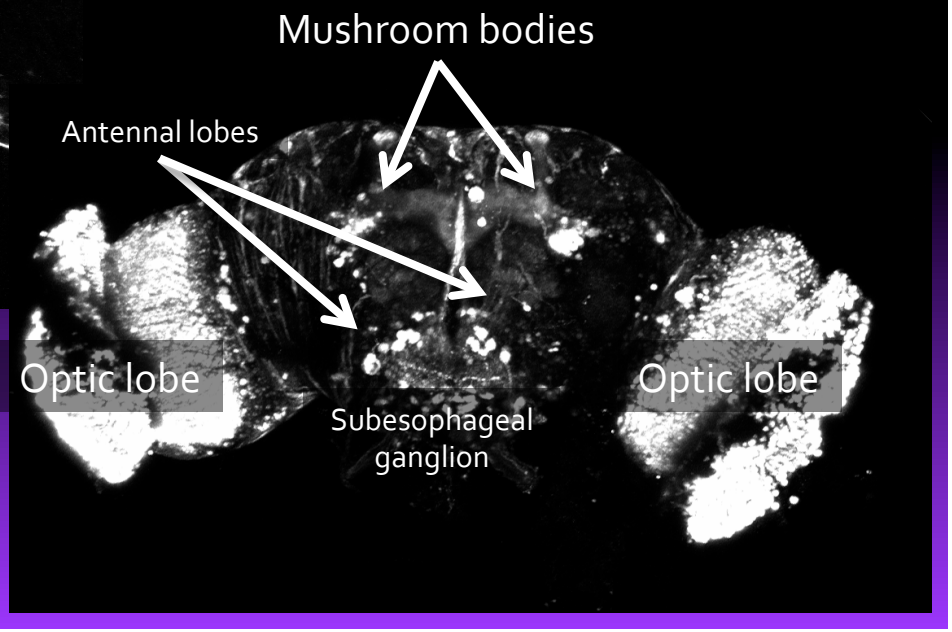
Jenett A, Schindelin JE, Heisenberg M. Wikipedia Common

Heisenberg M (1998) What do the mushroom bodies do for the insect brain? *Learn & Mem* 5: 1-10.
Heisenberg M (2003) Mushroom body memoir: from maps to models. *Nat Rev Neurosci* 4: 266-275.

Learning and memory: Different expression patterns of the mushroom bodies

GAL4-UAS expression of green fluorescent protein (GFP) in the mushroom bodies of *Drosophila melanogaster*:





Learning and memory: mushroom bodies

- The mushroom bodies have long been thought to be associated with learning and memory: http://en.wikipedia.org/wiki/Mushroom_bodies

Heisenberg M (1998) What do the mushroom bodies do for the insect brain? *Learn & Mem* 5: 1-10.
Heisenberg M (2003) Mushroom body memoir: from maps to models. *Nat Rev Neurosci* 4: 266-275.
Menzel R (1999) Memory dynamics in the honeybee. J Comp Physiol A 185: 323-340.
Menzel R (2001) Searching for the memory trace in a mini-brain, the honeybee. Learn & Mem 8: 53-62.

- Recordings from neurons in the mushroom bodies have shown that the neurons can be plastic:

Cassenaer S, Laurent G (2007) Hebbian STDP in mushroom bodies facilitates the synchronous flow of olfactory information in locusts. Nature 448:709-713.
Mauelshagen J (1993) Neural correlates of olfactory learning in an identified neuron in the honeybee brain. J Neurophysiol 69:609-625.

- The mushroom bodies also change and increase with experience

Experience- and Age-Related Outgrowth of Intrinsic Neurons in the Mushroom Bodies of the Adult Worker Honeybee . (2001) Sarah M. Farris, Gene E. Robinson, and Susan E. Fahrbach. The Journal of Neuroscience, 21(16):6395-6404.
Vision affects mushroom bodies and central complex in Drosophila melanogaster. (1997) M Barth, M Heisenberg - Learning & Memory. Learn. Mem. 4: 219-229.

Learning and memory: mushroom bodies

- Other brain areas likely involved in learning and memory are the central complex:

Liu G, Seiler H, Wen A, Zars T, Ito K, Wolf R, Heisenberg M, Liu L (2006) Distinct memory traces for two visual features in the *Drosophila* brain. Nature. 439:551-556.

- And the antennal lobe and the rest of the protocerebrum, though more research is needed to examine these possibilities

Menzel R (1999) Memory dynamics in the honeybee. J Comp Physiol A 185: 323-340.
Menzel R (2001) Searching for the memory trace in a mini-brain, the honeybee. Learn & Mem 8: 53-62.

- Ultimately, learning and memory can occur at many different levels of the brain, but much more research is needed to better understand how short, mid, and long term memory could occur in the insect brain, particularly considering all the connections we see:

Learning and memory: where else does it work in the brain?