ZOO332H1S - Lecture 4
Insect Nervous System and Escape Behaviour in the Cockroach

(AJE 2003)

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Periplaneta americana (L.) - also known as the American cockroach

SEM - Cockroach eye

SEM - Cockroach antenna

SEM - Cockroach tarsus

SEM - Leg sensory structures/climbing

2

Cockroach Eye

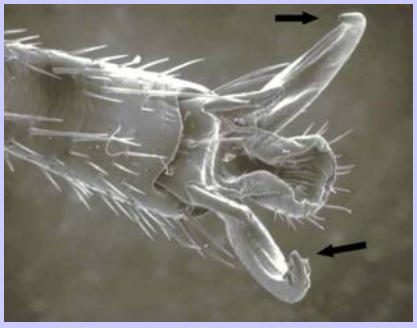
- Base of antenna
- Ocellus

3

Antennal segments

4

Leg - Tarsus and sensory spine(s)



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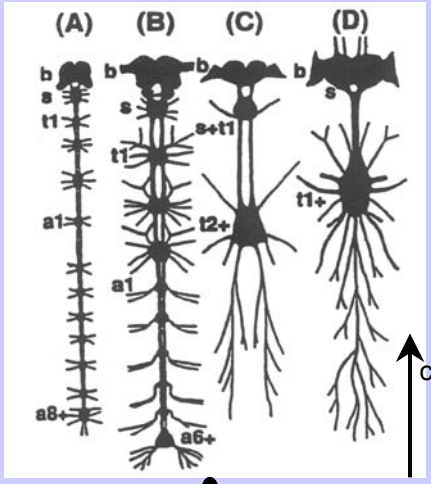
General form of insect CNS

- ganglia and connectives

- evolutionary tendencies

(A) stick insect; (B) ckrch; (C) blowfly; (D) fruitfly



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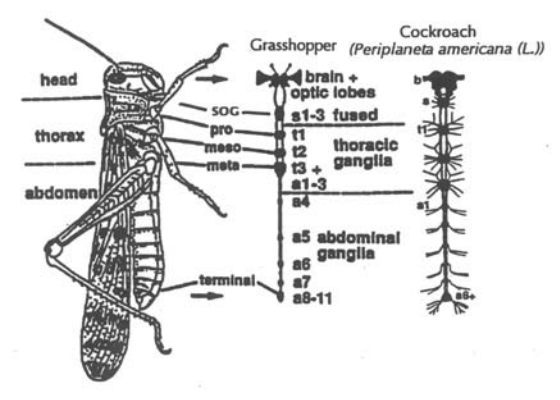
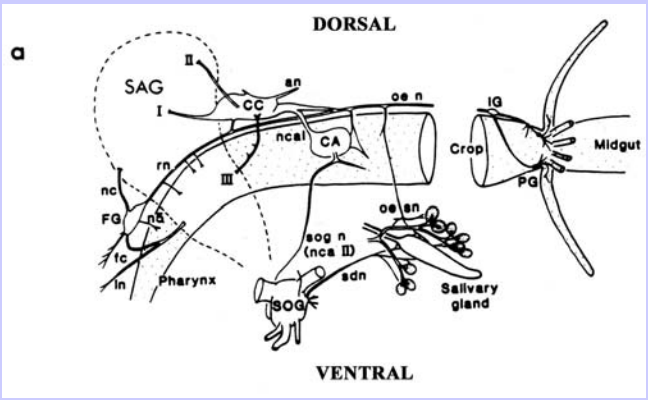
Cont...General form of insect CNS

Grasshopper and cockroach

- large thoracic ganglia
- fusion of "T3"
- nerve branches
- brain (SAG)

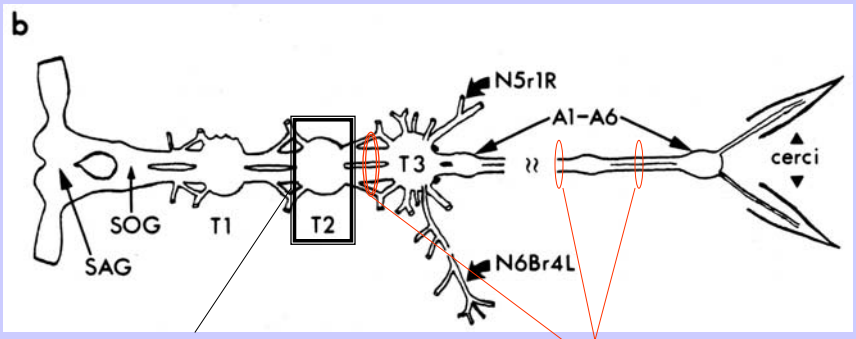


Cont….Cockroach Brain (SAG) and SOG



Lateral View

Cockroach Ventral Nerve Cord (CNS)



Ganglion - synapses; cell bodies; dendrites; tracts course through, some axons giving branches

Connectives - bilaterally symmetrical; carry axon tracts ("highways"); no cell bodies or synapses

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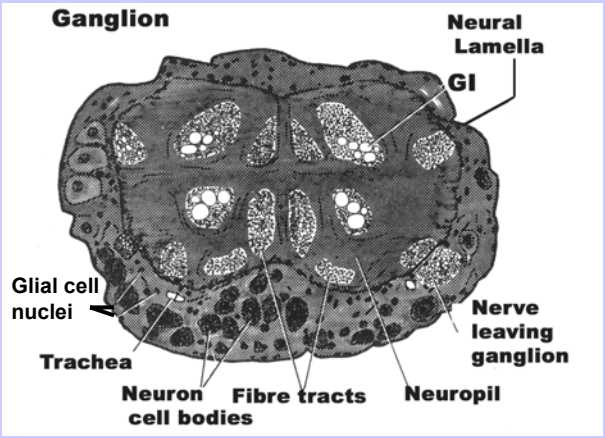
Cross-section through ganglion (redrawn from light micrograph)

- Cortex *vs.* neuropile
- tracts
- cell bodies
- dendrites
- giant interneurons



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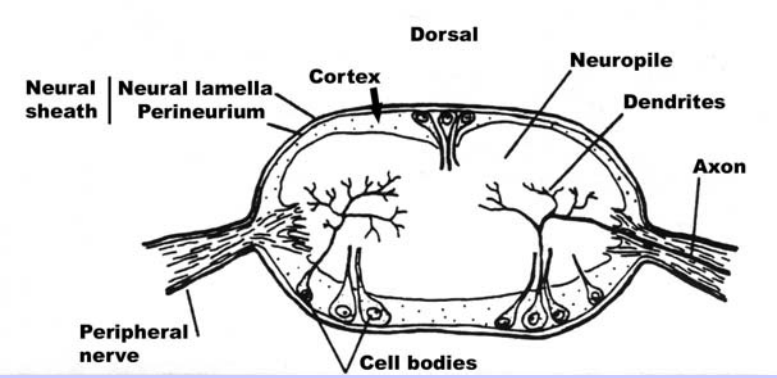
Simplified version of cross-section through ganglion



(after Pitman, 1985)

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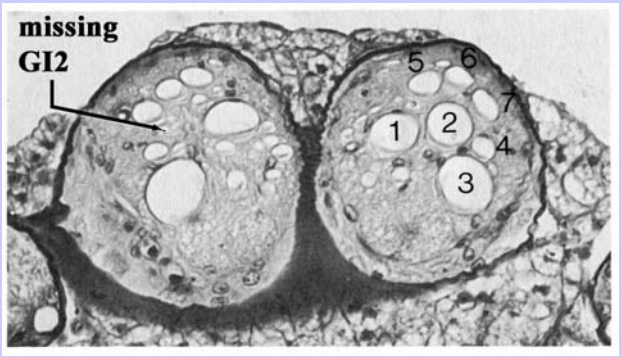
Organization of Insect CNS - Light micrograph of cross-section through connectives

- Symmetry
- axon types
- connective tissue
- missing GI2 (left side) - why?



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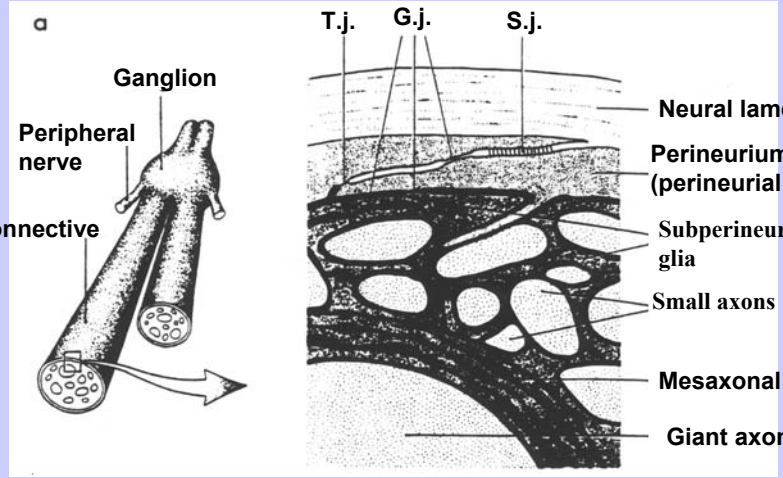
Cont.... Diagrammatic view of the organization of insect connectives (also part of the CNS)



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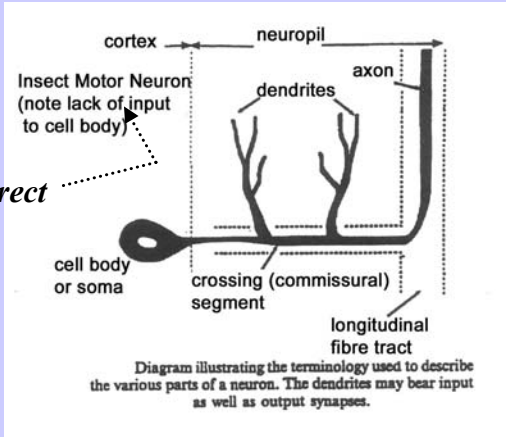
Single insect motor neuron

- basic structure

- complexity of dendritic arbor (later slides)



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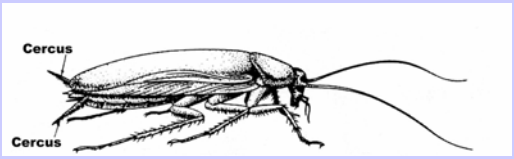
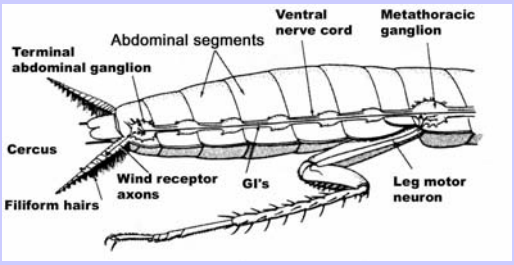
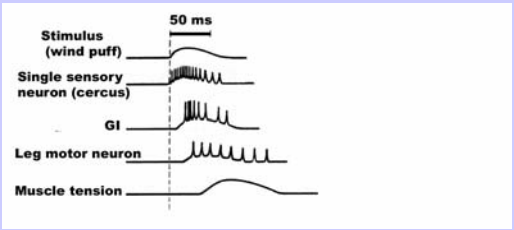
Cockroach wind receptors, escape circuitry, and behavioural response

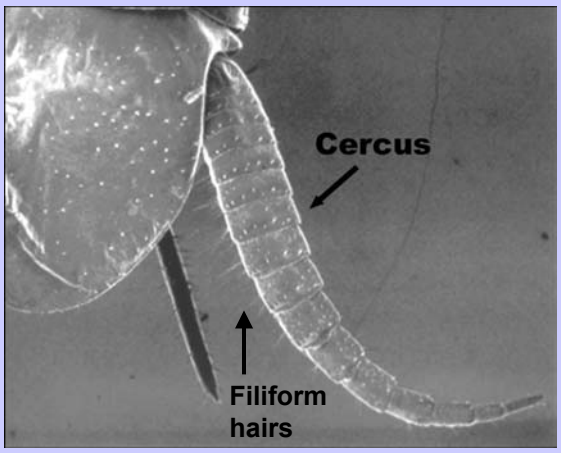






SEM of cercus (low mag)

- cerci extend from terminal abdominal segment
- filiform hairs



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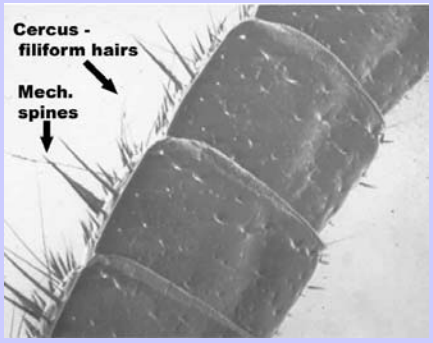
SEM of cercus (high mag)

- •Filiform hairs
- • *ca*. 220 per cercus
- •sensory neuron in base
- •other receptor structures



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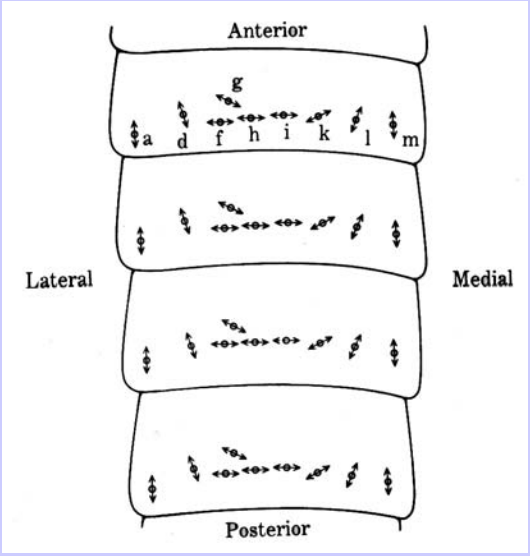
A note on filiform hair pliancy (and directional sensitivity)



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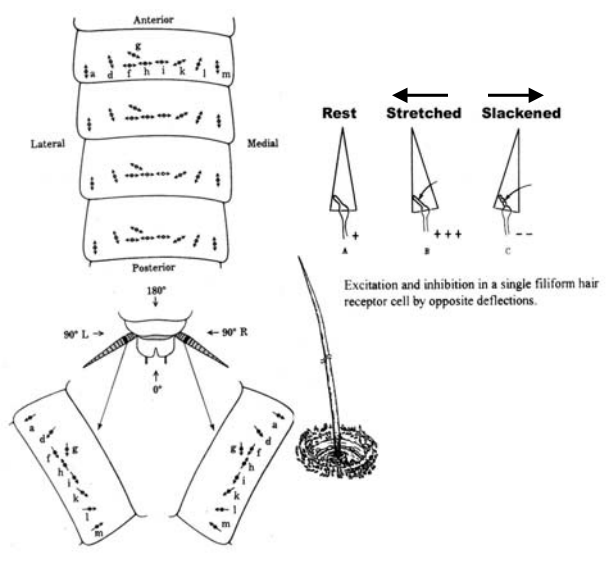
Filiform hair pliancy and directional sensitivity



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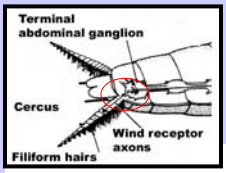
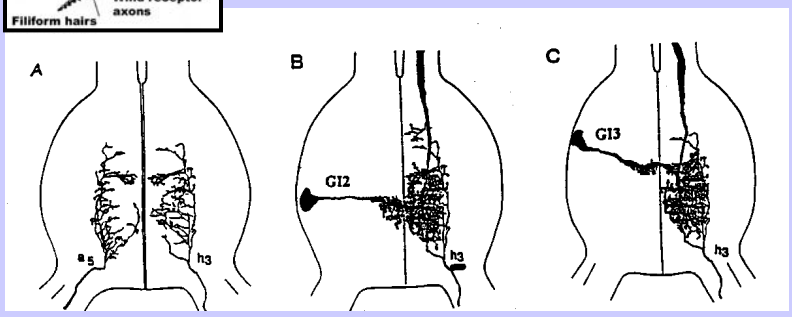
cont. - Cellular organization of insect CNS - Interaction in terminal abdominal ganglion (A6) between cercal afferents and GIs





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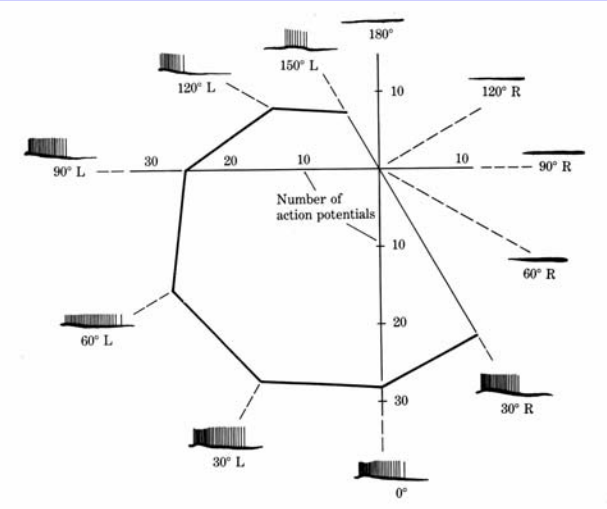
Coding is preserved in <u>individual</u> cercal afferent axons

- mean number of APs evoked from each angle is plotted



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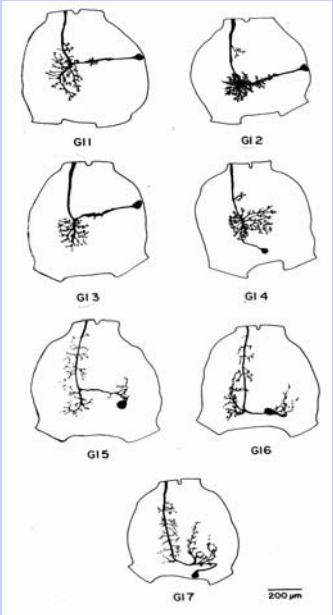
GIs in A6

- moving in afferent direction
- next neuron level in the pathway
- cell bodies located contralateral to axon (note that figure is distorted laterally)



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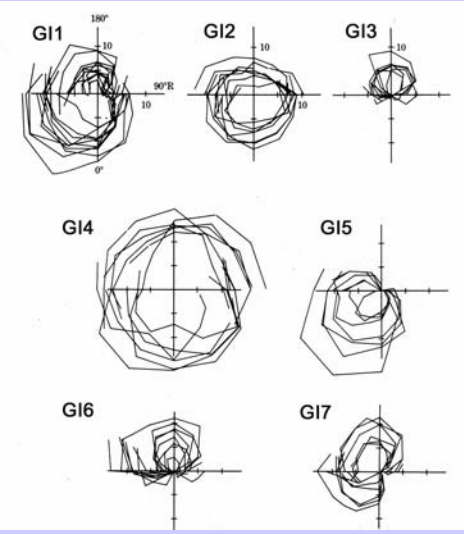
Coding is preserved in Giant Interneurons

- cercal afferents drive GI's
- GI's are bilaterally symmetrical
- 7 on each side
- position constant amongst animals
- intracellular recording from each while stimulate filiform hairs



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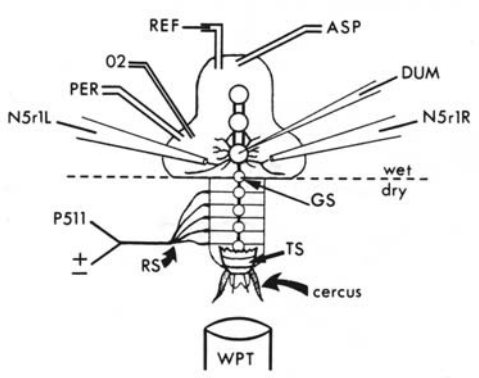
Recording apparatus -

Isolated (but "intact")
vs.
in situ (intact)



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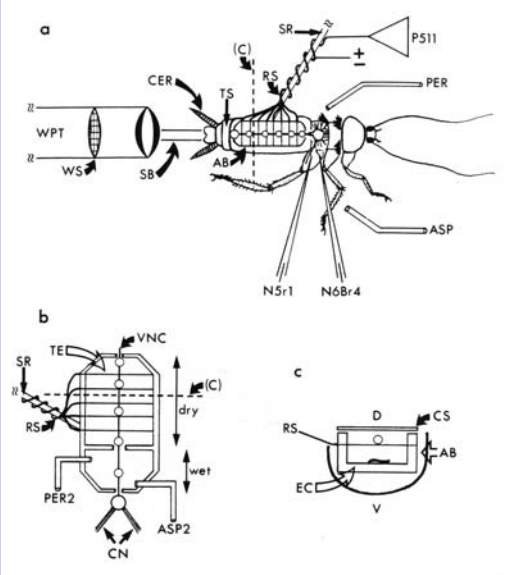
Recording *in situ* from AVNC and motor neurons (don't (!) memorize)



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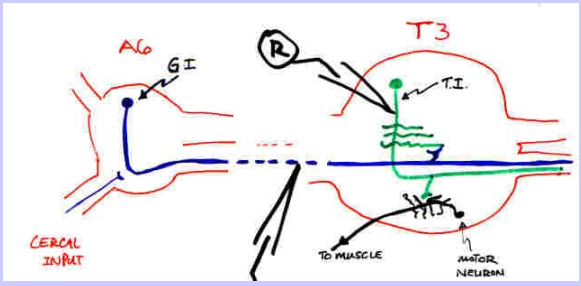
GI's **<u>indirectly</u>** drive leg motor neurons via interneurons

…and then there's "always" potential for neuromodulation



Record/Stimulate

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Modulation of circuitry in the CNS

Come back to later in the term…for now...

Some of the data supporting modulation of input to thoracic motor neurons

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Modulation of motor neuron circuitry in cockroach T3

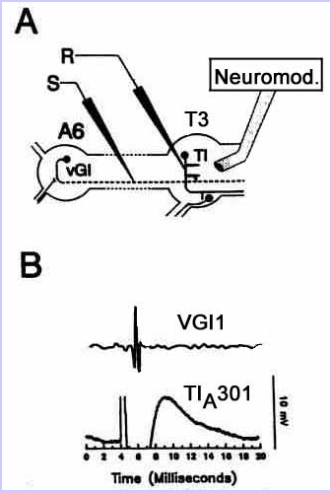
The setup

A

- **stimulate abdominal VNC**
- **record intracellular from GI**
- **neuromodulatory type substance applied**
- **wash off residual**

B

- record APs in vGIs
- record EPSPs in TIs



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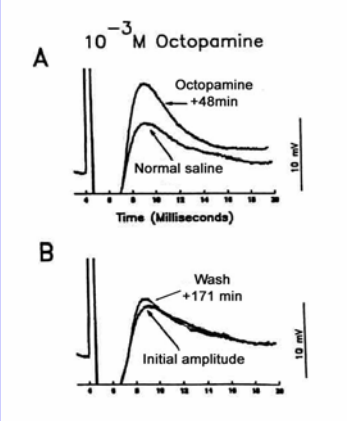
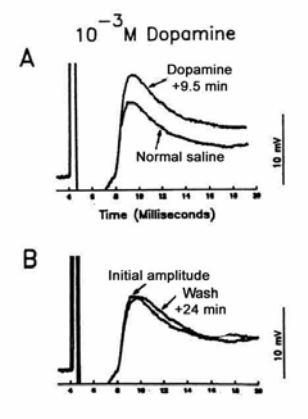
Octopamine (OA) and dopamine (DA) - putative neuromodulators

- **OA & DA effects on EPSP in TI**
- **OA > 2x more potent**
- **latency to initial and maximal effect similar - How are they (OA,DA) working?**





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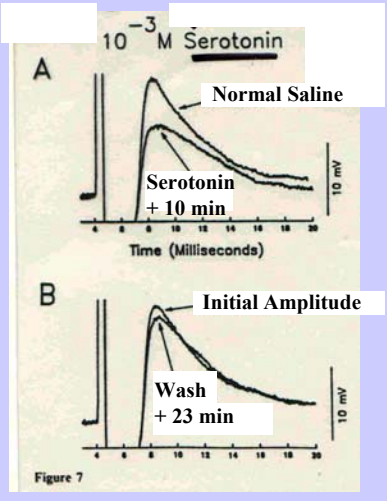
Further data supporting neuromodulation - serotonin

Cont...modulation of thoracic interneurons with input to motor neurons



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Some Summary Points:

- Octopamine - 100% increase in amplitude of EPSP
- Oct more than 2x as efficacious as dopamine (35% increase in ampl)
- Oct, DA > 10-15 min delay
- prolonged action - wash-out slow
- 2nd messenger (and access to circuit "restricted")
- degradation
- alone, no response on interneurons (no depolarization or EPSP)
- serotonin - decrease in efficacy of input to TIs when superfused
- rapid response of serotonin (30s to 2 min)

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Modulation makes sense

Inappropriate escape response - severe consequences (especially for gregarious animals)

1. Supported by previous studies - no inappropriate escape when walking; don't escape when touch in colony

2. **Aggregation pheromone** -

• detected by antenna ----interneurons synapse with escape circuitry

•cover antenna ---inappropriate escape

3. **Descending pathway** from head

4. Environmental influence = NB,

- brain to lower levels of the CNS

5. Is there a **tonic influence** from the brain?

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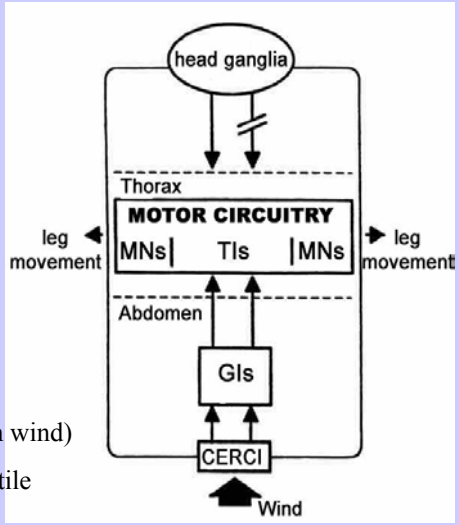
Modulatory inputs from the brain

- exp'al setup - cut right side of connective just caudal to brain
- animals appear "normal"
- BUT - normal response to wind from front left ?
- in 62% of cases, left wind, left turn!
- right front wind, left turn (away from wind)
- other sensory modalities (*eg*., leg tactile spine) OK in behaviour evoked



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Summary of Neuromodulation and inputs in T3

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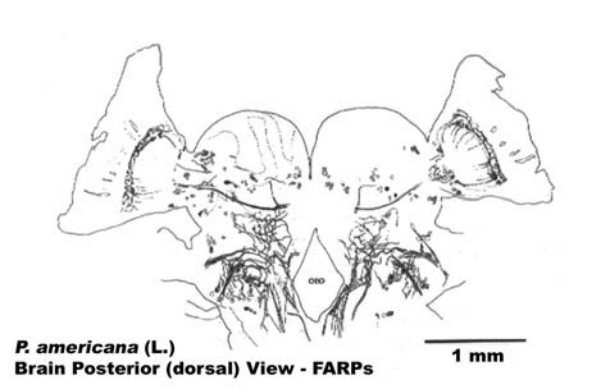
Cockroach Brain (SAG)



***P. americana* (L.)**
Brain Posterior (dorsal) View - FARPs

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