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

(AJE 2003)

1

***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)

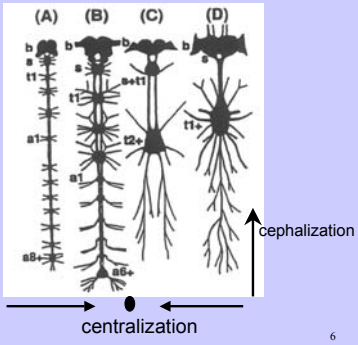
5

General form of insect CNS

- ganglia and connectives

- evolutionary tendencies

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

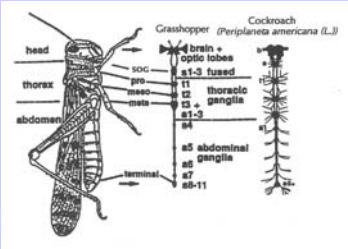


6

Cont...General form of insect CNS

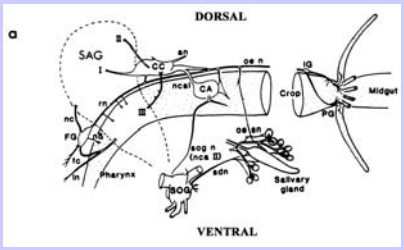
Grasshopper and cockroach

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



7

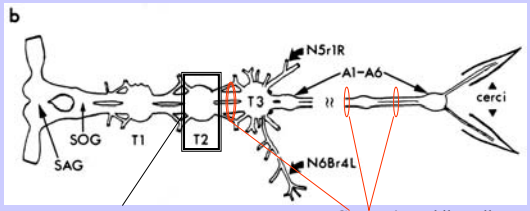
Cont….Cockroach Brain (SAG) and SOG



Lateral View

8

Cockroach Ventral Nerve Cord (CNS)



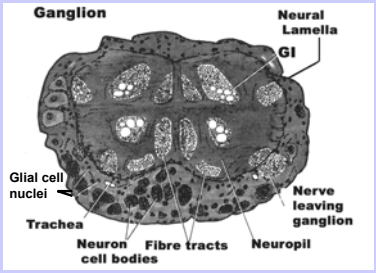
Ganglion - synapses; cell bodies; dendrites; tracts course through, some axons giving branches

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

9

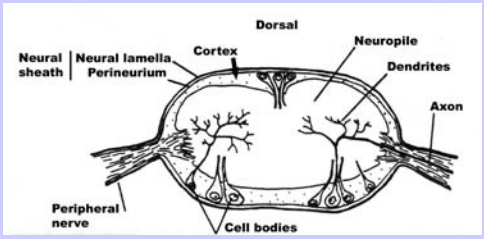
Cross-section through ganglion (redrawn from light micrograph)

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



10

Simplified version of cross-section through ganglion

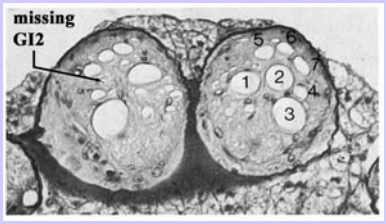


(after Pitman, 1985)

11

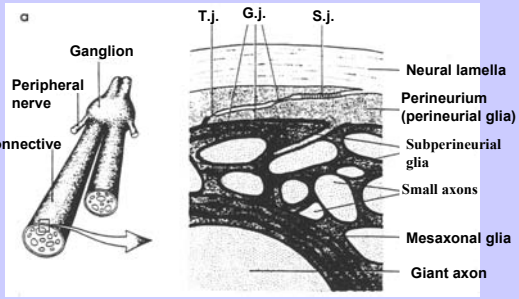
Organization of Insect CNS - Light micrograph of cross-section through connectives

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



12

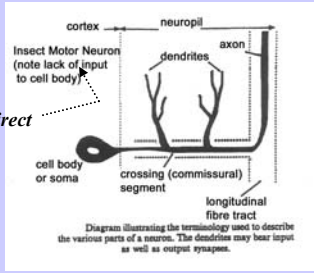
Cont.... Diagrammatic view of the organization of insect connectives (also part of the CNS)



13

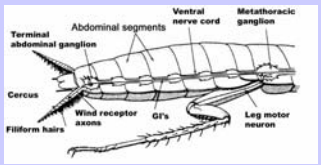
Single insect motor neuron

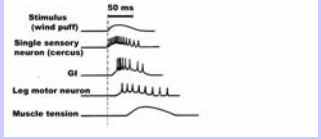
- basic structure
- complexity of dendritic arbor (later slides)



14

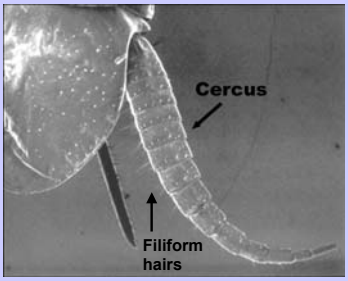
Cockroach wind receptors, escape circuitry, and behavioural response





SEM of cercus (low mag)

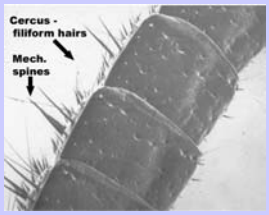
- cerci extend from terminal abdominal segment
- filiform hairs



16

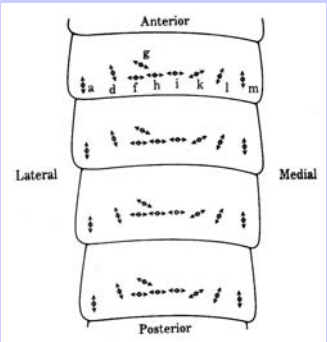
SEM of cercus (high mag)

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



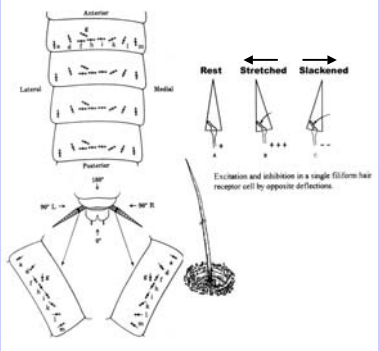
17

A note on filiform hair pliancy (and directional sensitivity)



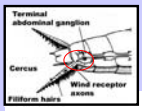
18

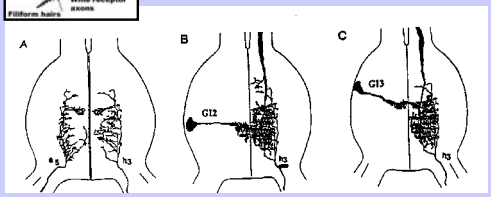
Filiform hair pliancy and directional sensitivity



19

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

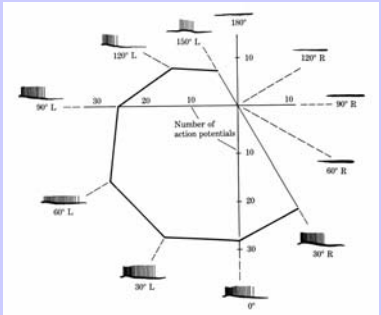




20

Coding is preserved in individual cercal afferent axons

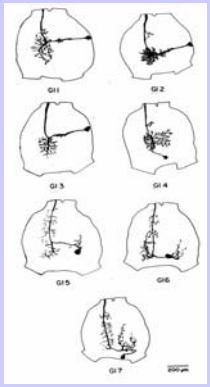
- mean number of APs evoked from each angle is plotted



21

GIs in A6

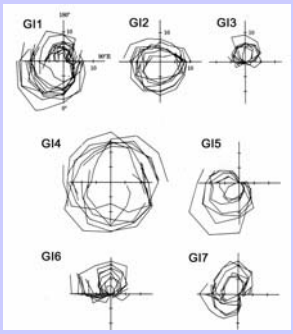
- moving in afferent direction
- next neuron level in the pathway
- cell bodies located contralateral to axon (note that figure is distorted laterally)



22

Coding is preserved in Giant Interneurons

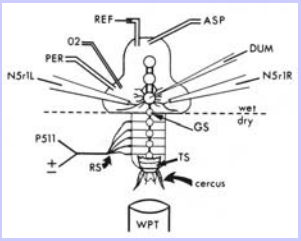
- cercal afferents drive GI's
- GI's are bilaterally symmetrical
- 7 on each side
- position constant amongst animals
- intracellular recording from each while stimulate filiform hairs



23

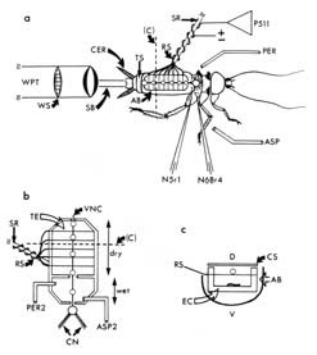
Recording apparatus -

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



24

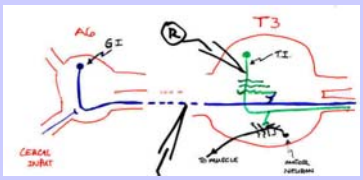
Recording *in situ* from AVNC and motor neurons (don't (!) memorize)



25

GI's **indirectly** drive leg motor neurons via interneurons

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



Record/Stimulate

26

Modulation of circuitry in the CNS

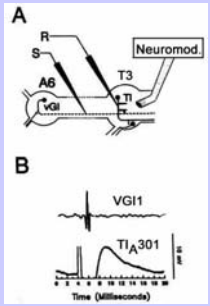
Come back to later in the term…for now...

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

27

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**

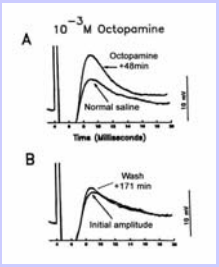
B

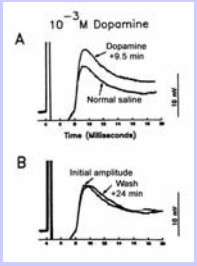
- record APs in vGIs
- record EPSPs in TIs

28

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?**

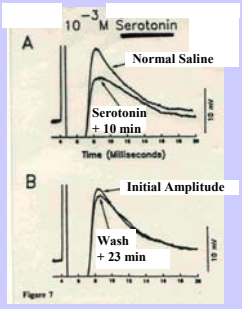




29

Further data supporting neuromodulation - serotonin

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



30

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)

31

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,

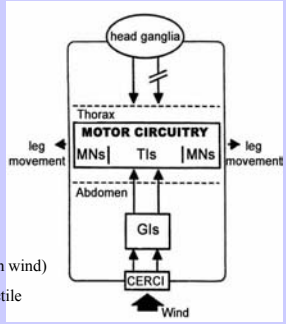
- brain to lower levels of the CNS

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

32

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

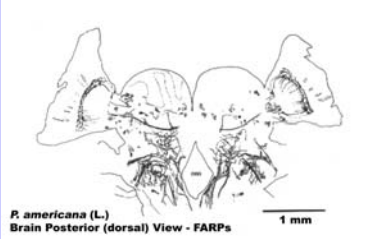


33

Summary of Neuromodulation and inputs in T3

34

Cockroach Brain (SAG)



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

35