Neural mechanisms of Cricket song

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http://blog.goo.ne.jp/fusami7/e/7dac8af6247c689f01564a5e3792066c
Calling song

Gryllus pennsylvanicus (Thomas Walker @ U. Florida)
Courtship song

*Gryllus pennsylvanicus* (Thomas Walker @ U. Florida)
Cricket auditory system

http://www.wfu.edu/biology/batsandbugs/bug_ears.htm

Huber ... Thorson (Sci Am, 1985)
Pressure-gradient receivers

Webb (Sci Am, 1996)
Walking wheels

Stabel ... Scharstein (*J Comp Physiol A*, 1989)
Cricket trackball

Huber ... Thorson (Sci Am, 1985)
Females prefer syllable rate of 30/s

Hedwig (J Comp Physiol A, 2006)
Cricket nervous system

Gryllus bimaculatus

http://invbrain.neuroinf.jp/modules/newdb1/extract/50/thumbnail/img1/koroZen.jpg
The Omega neuron (ON1)

Selverston ... Huber (J Neurosci, 1985)
Auditory response of the omega neuron

ipsilateral ear: excitation
contralateral: inhibition
Paired recording shows IPSP

Selverston ... Huber (J Neurosci, 1985)
Photoinactivation of a neuron

Selverston ... Huber (J Neurosci, 1985)
Killing the other Omega neuron removes inhibition
Ascending neuron 1 (AN1)

Figure from Huber & Thorson (Sci Am, 1985)
Effect of AN1 on phonotaxis

Huber (1990)
Trackball with high spatial, temporal resolution

The track ball can detect individual steps

Rapid reactive steering to sound


raw trace

averaged over 400 trials
Even a single pulse can trigger steering!

Species-specific song increases the gain

Poulet & Hedwig (PNAS, 2005)
Species-specific song increases the gain

Poulet & Hedwig (PNAS, 2005)
Male song production
Song production mechanism

Bentley & Hoy (Sci Am, 1974)
From motor neuron to song output

Bentley & Hoy (Sci Am, 1974)
Fictive singing is produced by rhythmic activity of wing opener and closer motor neurons.
A3-A0 is rhythmically active during fictive singing

Schöneich & Hedwig (Brain Behav, 2012)
A3-A0 passes the reset test!

Schöneich & Hedwig (*Brain Behav*, 2012)
Is activity of these neurons necessary for fictive singing?

Schöneich & Hedwig (Brain Behav, 2012)
Post-inhibitory rebound was observed

Schöneich & Hedwig (*Brain Behav*, 2012)
Interneurons important for singing

Figure 10. Overlay drawing of dendritic and axonal arborizations of singing interneurons in the metathoracic ganglion complex and abdominal ganglion A3. The conspicuous concentration of arborizations in the dorsal midline neuropiles of the metathoracic and first three abdominal neuropiles point toward these neuropiles as the location for singing pattern generation.

Schöneich & Hedwig (Brain Behav, 2012)
Command neuron for singing

Hedwig (J Neurophysiol, 2000)
Activation of this neuron is **sufficient** to elicit singing.
Hyperpolarization of this neuron stops the song

Hedwig (J Neurophysiol, 2000)
During singing, ON1 responds to syllables

During silent singing, ON1 shows IPSPs

Auditory response is inhibited during singing

The inhibition is not coming from sensory FB nor from the ears

Desensitization after singing

Inhibition protects from desensitization

The corollary discharge neuron!

Poulet & Hedwig (Science, 2006)
CDI is rhythmically active during fictive singing

Poulet & Hedwig (Science, 2006)
CDI does not pass the reset test

Poulet & Hedwig (Science, 2006)
CDI is not active during flight

Poulet & Hedwig (*Science*, 2006)
CDI is not auditory

Acoustic Stimuli:
4.8 kHz 85 dB SPL
Paired recording between CDI and auditory afferent

Poulet & Hedwig (*Science*, 2006)
CDI causes PAD in the auditory afferent

Poulet & Hedwig (Science, 2006)
Paired recording between CDI and ON1

Poulet & Hedwig (*Science*, 2006)
CDI causes an IPSP in the ON1

Poulet & Hedwig (Science, 2006)
Activation of CDI inhibits auditory response in ON1

Poulet & Hedwig (Science, 2006)
Activity of CDI is necessary for inhibition

Poulet & Hedwig (Science, 2006)
Cricket robot

Webb (Sci Am, 1996)