Neural Mechanisms 2

How Neurons Control Behavior
• Sensory receptors
• Relaying & responding to sensory input
• Central pattern generators (see textbook)

The Proximate Basis of Stimulus Filtering
• Stimulus filtering (see textbook)
• Cortical magnification

The auditory system of bats is adapted to detect ultrasound echoes. What about the auditory system of the bats’ prey?
• There are over 200,000 species of moths
• About 50% have ears
• Probably evolved for use in evading predation; moths that respond to approaching bats have a better chance of survival
Bimodal moth behavior in response to bat calls

Moth can hear the bat well before bat can detect the moth.

What are the neural mechanisms behind this bimodal moth behavior?
Most moths have only 2 auditory receptors, A1 and A2 (neurons), and one neuron of unknown function (B cell).

- A1 and A2 monitor the tympanic membrane, B fires tonically.
- A1 and A2 form the auditory nerve, which projects to the thoracic ganglia.
- Both A1 & A2 are sensitive to ultrasound.
Receptors in the ear (sensory neurons) relay information to interneurons in the thoracic ganglia, which communicate with motor neurons that control the wing muscles.
Moth ears are tuned to bat sounds

- Different moths are tuned to the bat species in that region
- An example of **stimulus** filtering
A1 cells of *Leucania pseudargyria* are most sensitive to:

A. 100 kHz  
B. 20 Hz  
C. 40 kHz  
D. 80 kHz  
E. 25 kHz
How moths might locate bats
Is bimodal moth behavior a result of 2 cell response?

A1 is more sensitive, A2 is less sensitive, but they share a similar frequency range (different thresholds, but same tuning)

Auditory threshold curves of a moth
Properties of the ultrasound-detecting auditory receptors of a moth

(A)

Neural activity
Low-intensity stimulus

Neural activity
Moderate-intensity stimulus

Neural activity
High-intensity stimulus

A1 receptor
Sound

A2 receptor
Sound
Kenneth Roeder (1966) proposed that A1 evokes “far bat” behavior, while A2 evokes “near bat” behavior
Auditory encoding during the last moment of a moth’s life

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The simple auditory system of nocturoid moths has long been a model for anti-predator studies in neuroethology, although these ears have rarely been experimentally stimulated by the sounds they would encounter from naturally attacking bats. We exposed the ears of five bat attack. Short of chronically recording the auditory responses of a free-flying moth under attack from an actual bat, the next best method would be to expose a moth’s ear to an actual sequence of echolocation calls that it would hear as a bat performs its attack. Recently, Triblehorn and Yager (2002)

Fullard et al. (1994) proposed a method to circumvent this problem by using the echolocation sequence recorded from a laboratory-trained big brown bat (Eptesicus fuscus), a species known naturally to eat moths (Black, 1972), as it attacked a small microphone that it expected to be an edible target.
A1/A2 responses to echolocation sequence

- Notodontid moths have only 1 auditory receptor (not two) – but still show two-part behavior. Roeder’s original hypothesis may need some refinement.
- A work in progress!
Absent          Search        Approach       Tracking      Terminal Buzz
Near BatFar Bat
Erratic, non-directional
diving response
Controlled, directed
flight away
Faint, slow Intense, rapidly repeated
Very close, rapid
Firing activated
Reduced firing
Spontaneous, slow firing
Increase in spike rate
Fast spike rate
Fast spike rate
No firing
No firing
No firing
No Bat
Far Bat
Near Bat
Normal behavior
Controlled, directed flight away
Erratic, non-directional diving response
http://www.youtube.com/watch?v=O8psKvn0_3w
Outline

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Avoidance of and attraction to different sound frequencies by crickets

(A) Silent

(B) 5 kHz

(C) 40 kHz
Avoidance of and attraction to different sound frequencies by crickets

Cricket ear

![Cricket ear image]

**int-1 interneuron**

![Neural circuit diagram]

**Intensity threshold (dB) for response**

**Sound frequency (kHz)**

3 4 5 6 8 10 20 40 60 80 100
How to turn away from a bat
How Neurons Control Behavior

The Proximate Basis of Stimulus Filtering

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Outline

(a) star-nosed mole
(b) eastern mole
(c) masked shrew
(d) hedgehog

http://www.youtube.com/watch?v=6m0PMcXK6XA
- Lives in wet, marshy soil
- Burrows in search of earthworms
- Worms cannot be seen
- Ignores visual information
- Relies on tactile information
- Appendages 11 are heavily used

Mouth

nostril
Sensory nerve terminals

Eimer’s organs

A single Eimer’s organ

Epidermis

Dermis

10 μm
The cortical sensory map of the star-nosed mole

- Anesthetized moles
- Recorded action potentials in cortical neurons
- Touched different parts of nose
- Created a “map”
- Appendages 11 get disproportionate representation
The cortical sensory map of the star-nosed mole

- Appendages 11 get disproportionate representation
- Allocation of brain tissue is not equal
Sensory analysis in four insectivores

(a) star-nosed mole  
(b) eastern mole  
(c) masked shrew  
(d) hedgehog

• Allocation of brain tissue is not equal

• Is there a tradeoff?