L31. Neural Circuits for Escape and Startle
...and what it says about decision making in the Nervous system

Motor Behavior

Motor control of escape and startle as examples of:

- Coordination of multiple muscle groups
- Appendages
- Limbs
- Speed
- Stereotyped, repetitive acts
- Decisions

Decision making: a motor hierarchy

Command Neuron Concept

- Keis Wiersma & Ikeda (1964)
  - Interneurons in crayfish tail
  - Electrical stimulation of single cell evoked coordinated movement (swimmeret movement, posture control, escape)
  - Pattern of stimulation was unimportant

Escape

- Rapid: Latency can be less than 10-20 ms
- All or none (decisive!)
- Complex: many actions coordinated.
- Dominant: once initiated, blocks all other behavioral acts.
- Illustrates decision making properties of command neurons.

Escape: the nervous system of the crayfish

Flexion Escape Control by Giant Interneurons

Anatomy of Escape
Lateral Giant Escape
mechanical stim. to tail
rostral segments flex.
abrupt, single flexion drawing tail
upward. Somersault.

Medial giant escape.
anterior stimulation (visual,
mechanical)
All segments flex
tail flip, propels animal
backward.

Extended Escape Swimming
NON-GIANT ESCAPE
Extended swimming: flexion, extension at 20 Hz.
Multiple contractions.
Does not involve lateral or medial giants (except for first
flip)
• weaker and slower than MGI escape or LGI escape.
• multiple forms: linear flips, twisting flips, pitching flips
(following medial giant: linear flips only; following lateral
giant: pitching flips)

Speed of Response
Latency of flexion response is 10 ms

Electrical synapses (fast)
large neurons (fast conduction velocity)
large synapses (strong EPSP)

Physiology of Escape
Electrical stimulation of LGI evokes spike in motor giant.
Delay: short, electrical synapse
Recording from LGI in response electrical stimulation at sensory receptor neuron. Note two
synaptic events: alpha and beta
LGI Escape Circuit

Mechanosensory Input: ~1000 sensory hairs on tail. Sensory fibers (tail afferents) are directionally sensitive. Tuned. 80 Hz input (no response to small, low Freq. wave action). Sensory interneurons: receive inputs from sensory afferents. Afferent output to lateral giants via alpha pathway (direct, electrotonic); beta (indirect, chemical).

Lateral Giant

Short latency EPSPs from sensory hairs (both direct and indirect). Electrical synapses are below threshold: many required to stimulate giant. Lateral Giant makes decision to act.

LGI fires: tail flip (LGI is sufficient)

Lateral giant is essential to action (necessary):
1) hyperpolarization of the lateral giant will block the response to normal stimuli.
2) the amount of hyperpolarization needed to block the tail flip is exactly the same as that needed to block LGI from spiking.
3) In hyperpolarized cell, the EPSP gets increasingly larger and larger with increased stimulus, but does not fire a spike. No behavior. LGI is the decision cell in this circuit.

Graded EPSP with increasing stimulus strength shows that input to LGI is gradual.
Threshold is sharp. LGI is decision making cell (all or none).

Kupfermann and Weiss


Neuron must be both necessary and sufficient for behavior.
LGI as Executive Neuron

Once the command is given to act, additional control must be exerted in order to inhibit competing behavioral acts. This is the executive function of a Command Neuron.

**Inhibition of extensor muscles:** (3 pathways):
- Excite extensor muscle inhibitors
- Inhibit motor neurons on fast extensor muscles
- Inhibit muscle receptor organs that normally respond to extension stretch.

LGI neurons cause widespread inhibition following command discharge.

Flow diagram for escape responses in crayfish

Modification of Escape

- Restraint
- Feeding
- Learning (habituation)

Other Examples of Escape

- Power dive in noctuid moth
- Wind-driven escape in cockroach
- Acoustic startle reflex
- C-start reflex in fish
Escape in Fish


Lessons from escape behavior

- Escape behavior is highly adaptive (essential), rapid, evoked by stimulus. An extreme case of decision making (very decisive).
- In crayfish and in teleost fish, mediated by giant interneuron(s).
- Different forms of behavior depending upon which cell is activated.
- Command neurons: necessary and sufficient to produce entire behavior.
- Behavior is complex: involves sequence of acts, excitation of some cells, inhibition of others. Executive action of command neurons.
- Command neuron’s function is modulated by many factors, including learning.