

GAP-FREE NEURAL CIRCUITS – CLASS #8: *C. elegans* mating

OUTLINE:

- Sexual dimorphism
- Mating behavior
- Neural control of mating steps

Sexual dimorphism

- 2 sexes
 - Hermaphrodites – contain sperm and eggs – can self – XX
 - Eventually run out of sperm after producing 300 fertilized eggs in 3 days
 - Males – contain sperm only – need herm. to reproduce – XO
 - Male sperm out-compete hermaphrodite sperm at fertilization
- Male-specific anatomy of the tail [DRAW]
 - Rays (9 pairs)
 - Deflected by body of hermaphrodite
 - RnA & RnB per ray
 - 1, 5 and 7 open dorsally
 - 2, 4 and 8 open ventrally
 - 3 and 9 open laterally
 - 6 has no sensory opening
 - R5A, R7A and R9A are dopaminergic
 - R1B, R3B and R9B are serotonergic
 - Spicules (2)
 - Male thrusts at vulva
 - SPD & SPV per spicule
 - SPC innervates spicule protractor muscles
 - Hook sensilla (1)
 - Function not as obvious
 - HOA & HOB
 - Post cloacal sensilla (PCS) (2)
 - Function not as obvious
 - PCA, PCB, PCC per sensillum
- Male-specific nervous system (81 male-specific)
 - 383 neurons vs. 302 in hermaphrodite
 - 4 extra neurons in head (CEM) with remaining in tail
 - CP ventral cord neurons are serotonergic
 - Male tail is almost like a second brain
 - Missing neurons that control vulva opening
 - Connectome just finished

Mating behavior

- Male behavior
 1. Search: Chemotax toward hermaphrodite
 - Hermaphrodites secrete ascarosides which attract males
 - In fact, males will leave food searching for hermaphrodites; this is suppressed if herms are present on food
 2. Contact: Touch the hermaphrodite with ventral side of tail
 3. Stroke: Search for vulva by moving backwards
 4. Turn: When reach end of animal, turn and stroke other side
 5. Locate: Find the vulva
 6. Insert: At vulva, prod with spicules to enter (5-7 Hz)
 7. Ejaculate: Pump seminal fluid into uterus
 - Sperm will crawl to spermetheca
 - Plug can form over vulva, reducing mating efficiency by other males
 8. Leave
SLIDES (1)
- Hermaphrodite behavior
 1. Sprinting, in response to male contact
 2. Sperm expulsion, by contraction of uterus

Neural control of mating steps

1. Search: Chemotax to hermaphrodite
 - Q: Does this behavior require male-specific neurons, or common neurons with modified function?
 - Requires the TRP channel gene *osm-9*, which is responsible for inward current
 - *osm-9* expression gave a list of 15 neuron classes (~30 neurons total)
 - AWA (also senses diacetyl)-----| AIY
 - AWC (also senses isoamyl alcohol)
 - CEM (male-specific neuron) – connectivity incomplete
 - An example of “rewiring”? Ablations at younger stage don’t yield a defect.
 - *fem-3* overexpression results in hermaphrodites with a male nervous system but hermaphrodite anatomy
 - Masculinized hermaphrodites are attracted to pheromones like males
 - SLIDES (3)
2. Contact: Respond to touching the hermaphrodite
 - 1) Halt forward motion
 - 2) Place ventral side of tail against hermaphrodite
 - **Ablations: ablated a precursor cell in the embryo or early larvae, then narrow**
 - Rays 1-6 (anterior)
 - No contact response at all, to either dorsal or ventral contact
 - Rays 1, 5 and 7 (open dorsally)
 - Necessary and sufficient (amongst rays) for response to dorsal contact

- Rays 2, 4 and 8 plus the hook, PCS and spicules (open ventrally)
 - Redundantly act for ventral contact response
- 3. Stroke: Move backwards, trying to locate the vulva
 - Rays 2, 4 and 8 plus the hook, PCS and spicules
 - Redundantly act for backward swimming after tail is positioned
- 4. Turn: When reach head/tail, make tight ventral coil to stroke other side [LOOP]
 - Rays 7, 8 and 9 (most posterior rays)
 - Ablation leads to late-turn and loss of herm. contact
 - So likely sense tapering of herm. body to initiate turn
 - Rays 5A, 7A and 9A (dopaminergic)
 - Ablation leads to sloppy, large ventral coil with timing intact
 - CPs (serotonergic)
 - Required for ventral bend
 - Input from R1, R2, R3, R6, R7, R8, R9
 - Synapse onto diagonal muscles
 - Diagonal muscles
 - Required for ventral bend
 - SLIDES (5)
- 5. Locate: Find the vulva
 - 1) Approximate: HOA and HOB (hook neurons)
 - Hook is “tripped” by the vulva to locate it
 - If lost, can protract spicule and use that instead to find vulva (“slow search”)
 - 2) Precise: PCA, PCB, PCC (PCS – at least 2 must be present)
 - Release ACh onto protractor muscles to cause rhythmic thrusting
 - Required for “slow search” vulva-finding with protracted spicule
 - Only occurs in the presence of the vulva (so likely cue secreted through vulva?)
 - SLIDE (1)
- 6. Insert: Use spicule to penetrate vulva
 - Periodic prodding (7 Hz): Hook & PCB and PCC
 - Sustained protraction: SPC
 - SPC senses spicule insertion and secretes ACh onto protractor muscles to sustain insertion
 - Prodding may occur for as long as 10 minutes in young hermaphrodites
 - Prodding can be as fast as 10 seconds in old hermaphrodites
 - Gonad
 - Required for prolonged spicule protraction (from 30 s to 60 s)
- 7. Ejaculate
 - SPV
 - Required for releasing sperm transfer from inhibition
 - Without it sometimes sperm is released outside vulva
- Weaknesses

1. Only inactivation by ablation (no physiology or activations)
2. No epistasis analysis to flesh out the order of the circuit
3. Very unclear how each module interacts with the next

MAIN MESSAGE: A sequential, flexible motor program likely controlled by a small set of interdependent sensory-motor circuits