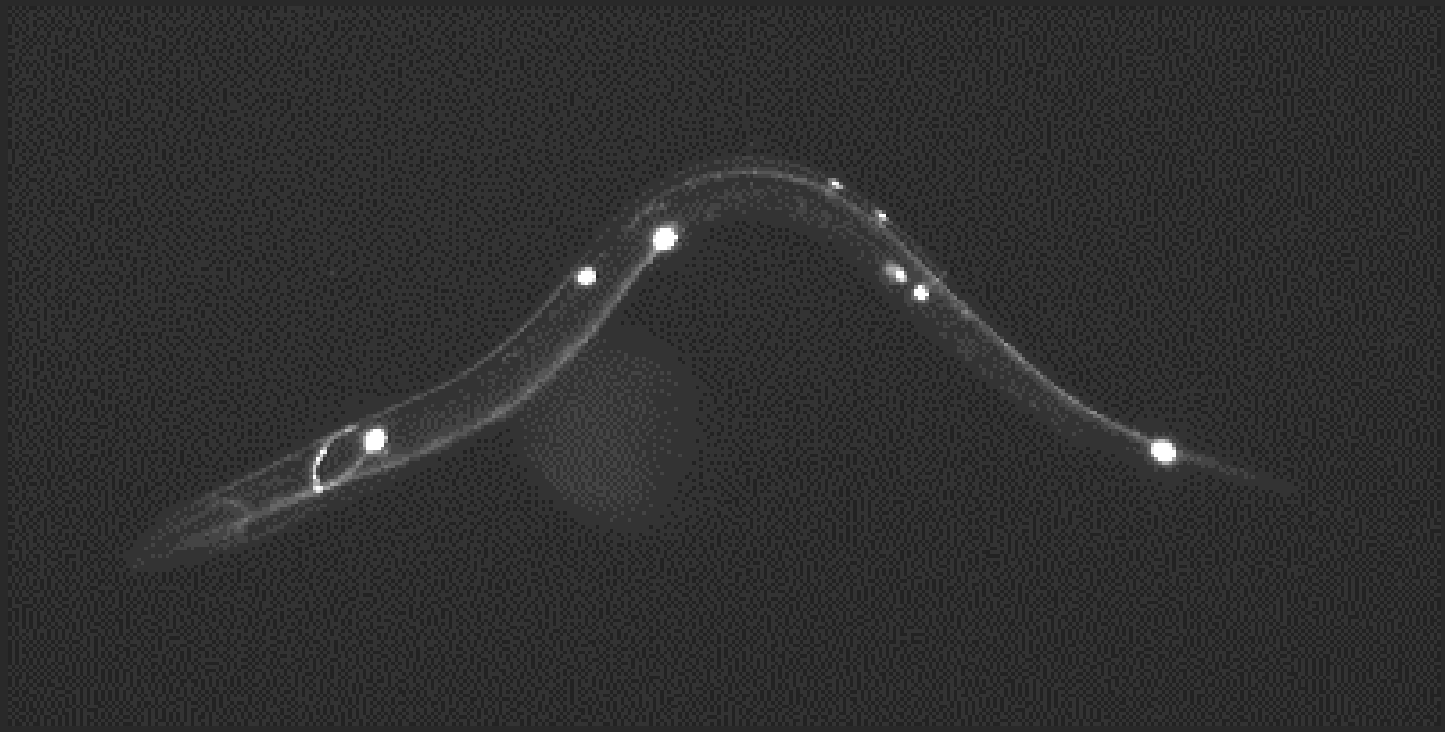
Neural circuits for touch-induced locomotion in *C. elegans*



Nikhil Bhatla

January 9, 2013
MIT IAP

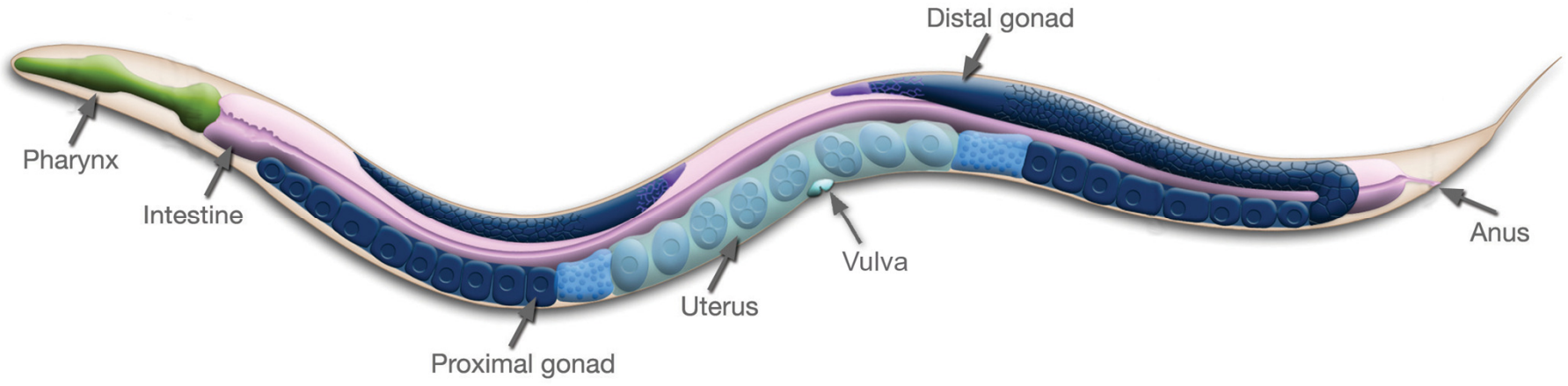
This is a *C. elegans* worm

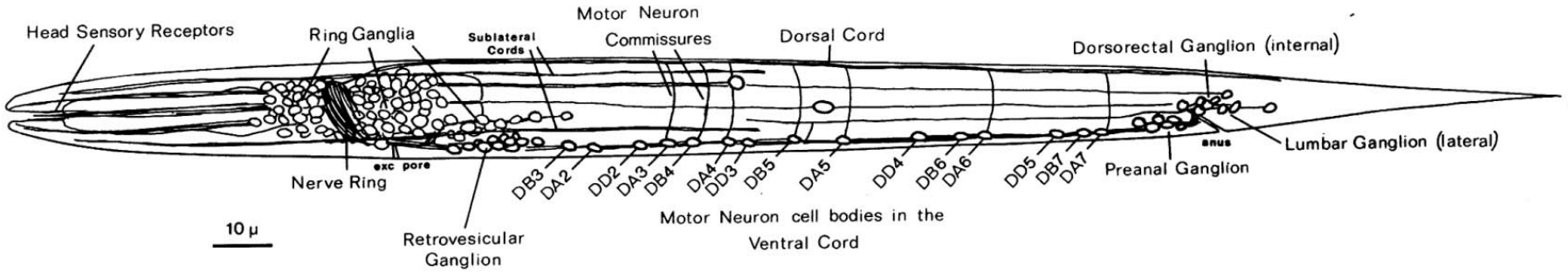
2 mm

Adult hermaphrodite

Video speed is real-time

The connectome of *C. elegans* is known

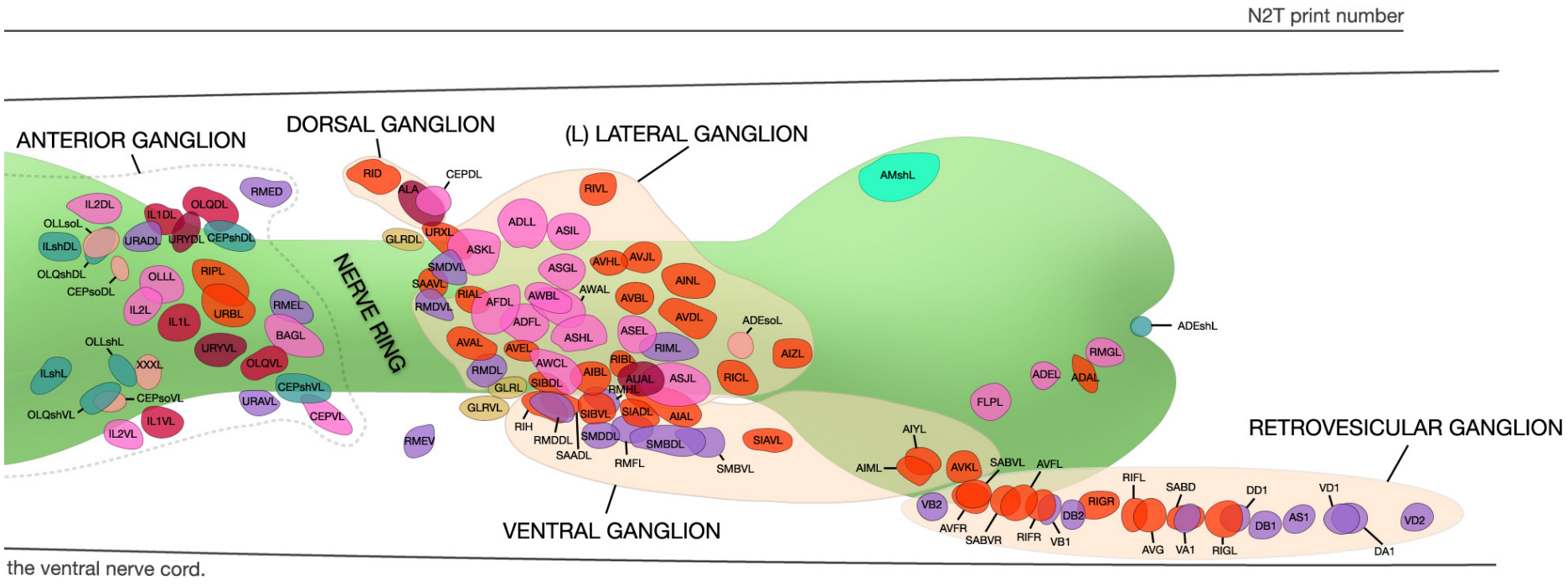




Each worm has exactly 302 neurons,
with about 7,369 chemical synapses & 975 gap junctions

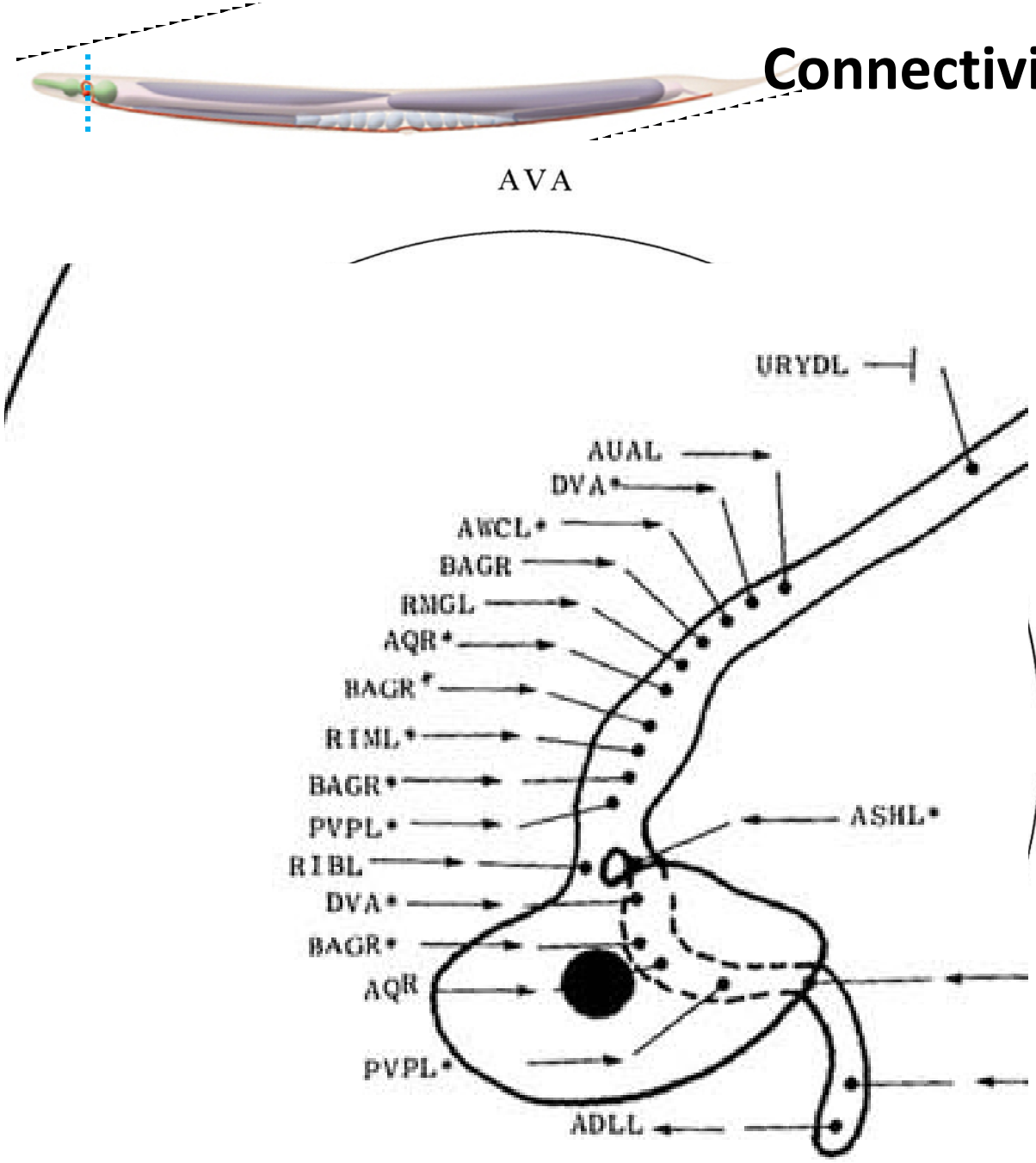
Schematic: Durbin 1986

A neural map of the *C. elegans* head



Only cell bodies shown (processes excluded)

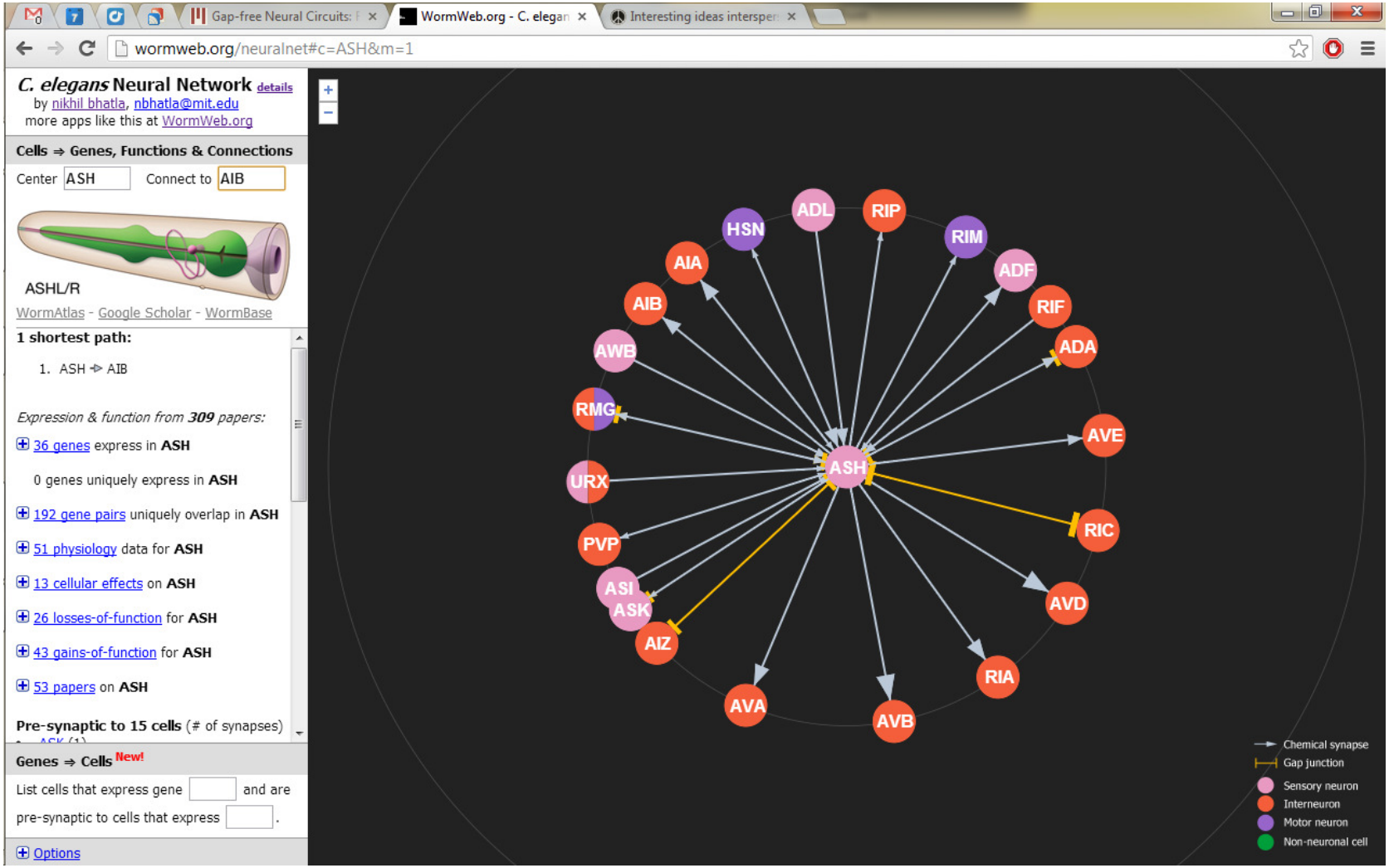
Connectivity map of AVA neuron



AVA ventral cord synapses (MoW Table Guide)			
partners	gap junctions	synapses from	synapses to and corecipients
PVC	10	3+11 m	7, 5 LUA, 4 PVC, 4 DA8, 2 PDE, VA10, DB5, VA4, DB3, DA7, DA5
VA11	8	-	6 AS11, 3 DA8, 2 DA9, VA12, VA10, VD13
DA8	1	-	4 PVC, 3 VA11, 2 AS11, VA12, DA7, DA9, VA10, VD13
DA4	5	-	3, 4 DA3, 2 DA5, 2 VA3, VA4
VA10	2	-	1, 3 AS10, 2 DA7, PVC, VA11, AS11, DA8
DA5	5	-	2, 3 VA5, 2 DA4, PVC, DA6
DA3	2	-	2, 4 DA4, 2 DA2, VA3
AS11	-	-	6 VA11, 2 DA8, VA10
DA7	2	-	2 AVA, 2 VA10, AS10, DA8, PVC
VA5	6	-	3 DA5, VA6, AS6, DA6
LUA	-	1 + 19 m	5 PVC
DA9	-	-	2, 2VA11, DA8
AS5	2	-	3VA6, AVB
DA1	8	-	2, AVA, SABD
AS10	1	-	3VA10, DA7
VA4	3	-	PVC, DA4, AS4, DB3
DA2	3	-	1, 2DA3, AVE
VA6	5	-	3AS5, VA5
VA3	3	-	1, 2DA4, DA3
AVE	-	8+30 m	2AS3, AS1, DA2
AVA	4	3m	2DA7, DA1

White..Brenner 1986

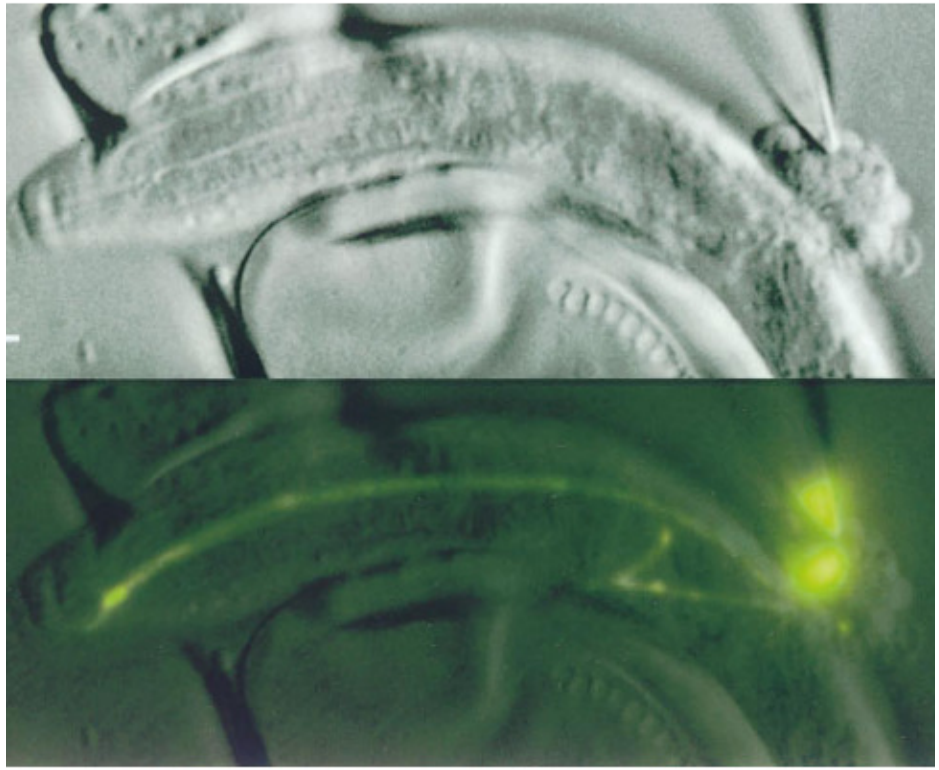
Interactive neural network browser

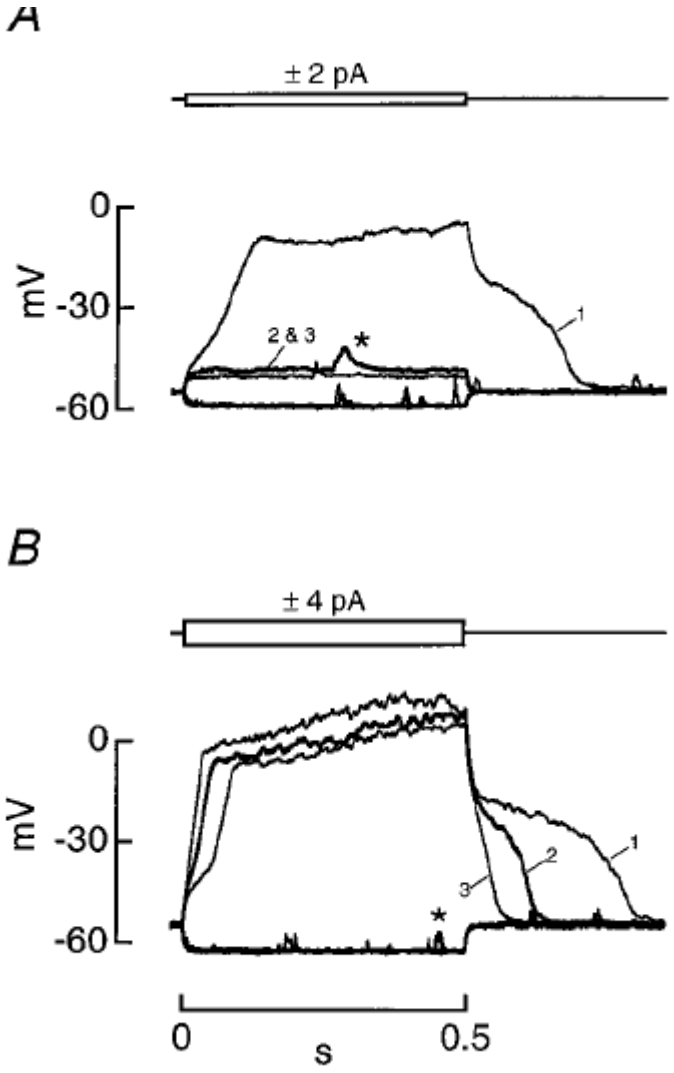


http://wormweb.org

Non-spiking electrical activity of *C. elegans* neurons

Patch-clamp recording of ASER, a sensory neuron for chloride



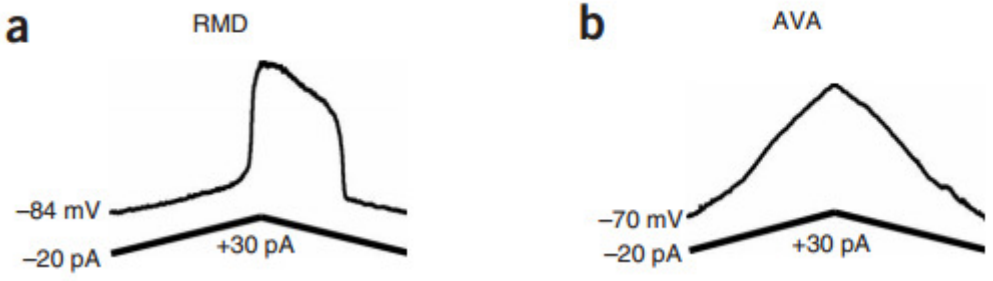


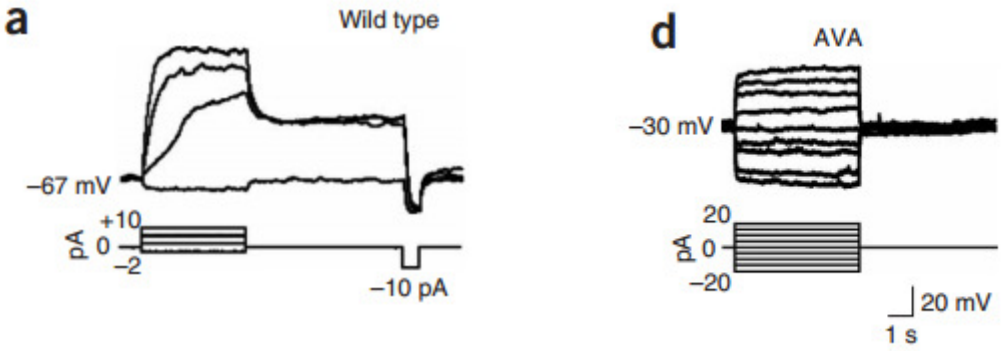
Goodman..Lockery 1998

Non-spiking electrical activity of *C. elegans* neurons

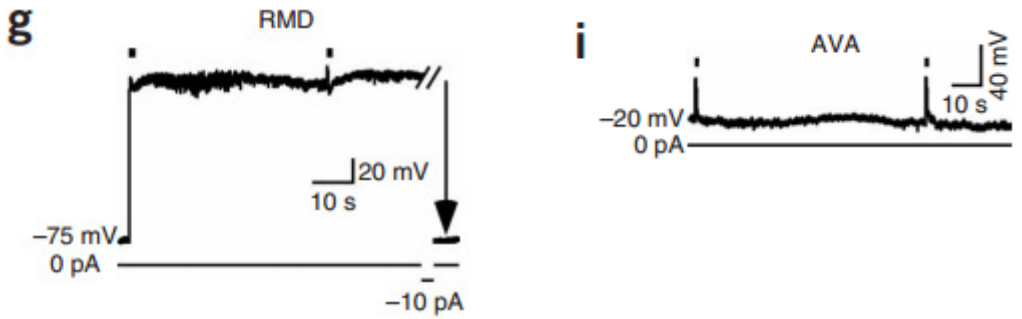
plateau potential **graded potential**

Responses to current:

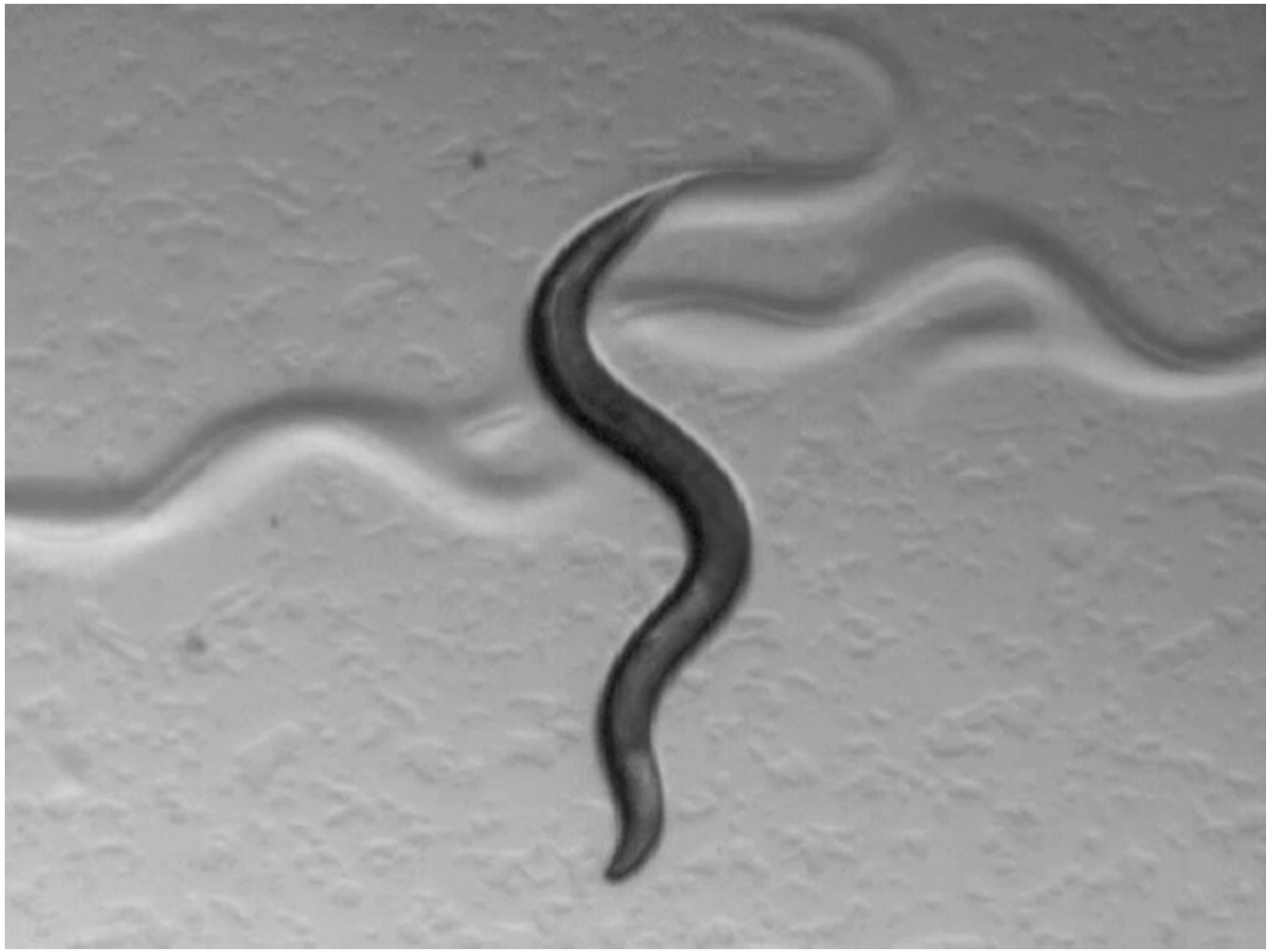




Responses to glutamate (*):



C. elegans reverses with anterior gentle touch

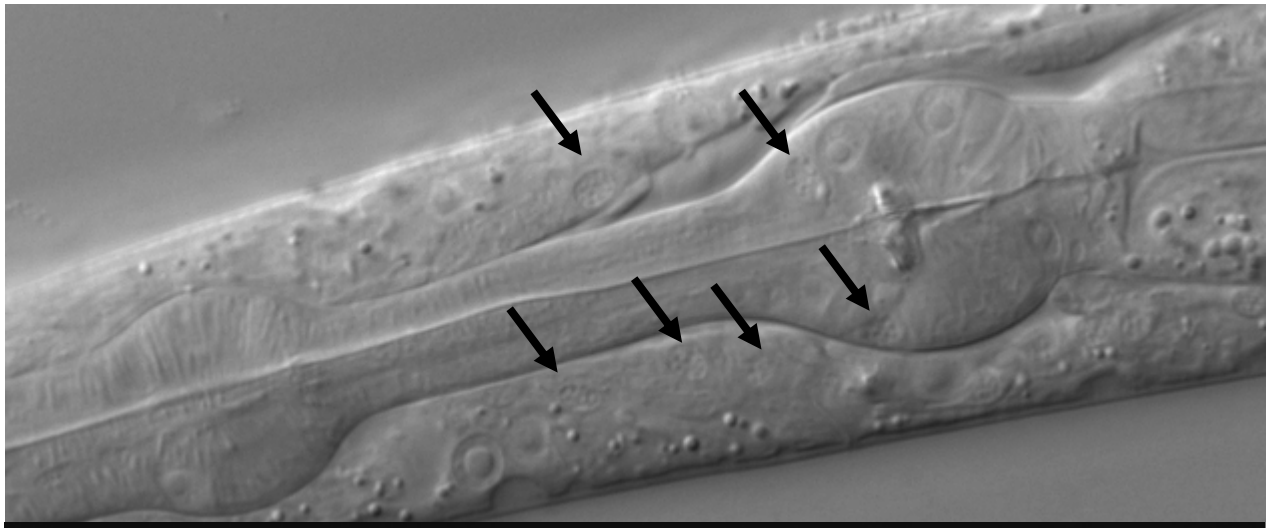


Video speed is real-time

Li..Xu 2011

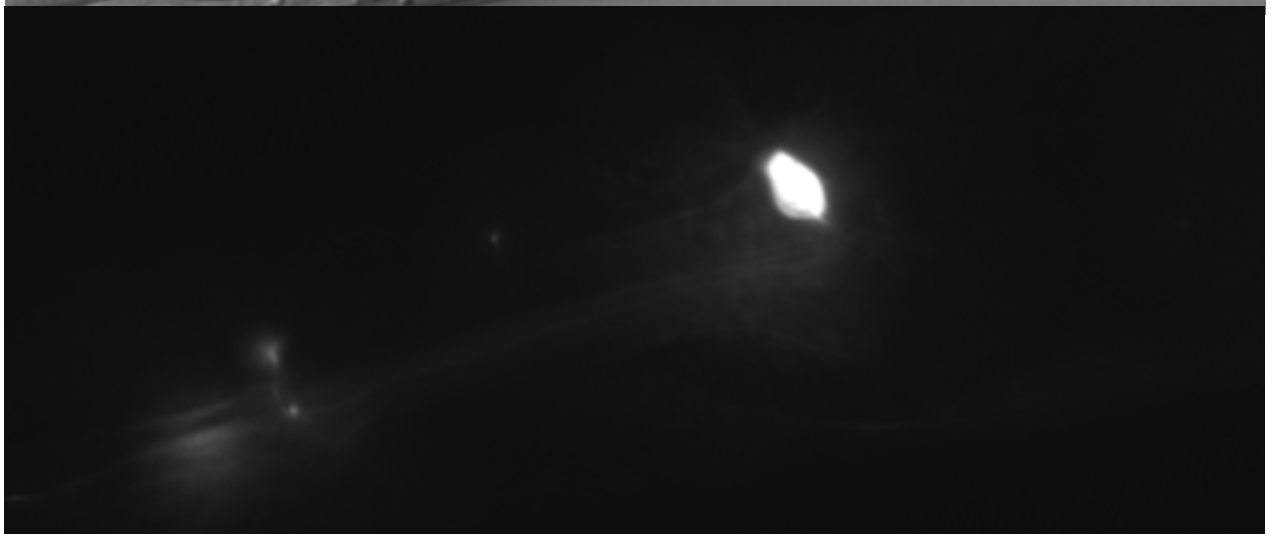
Identifying neurons for laser ablation

DIC optics:



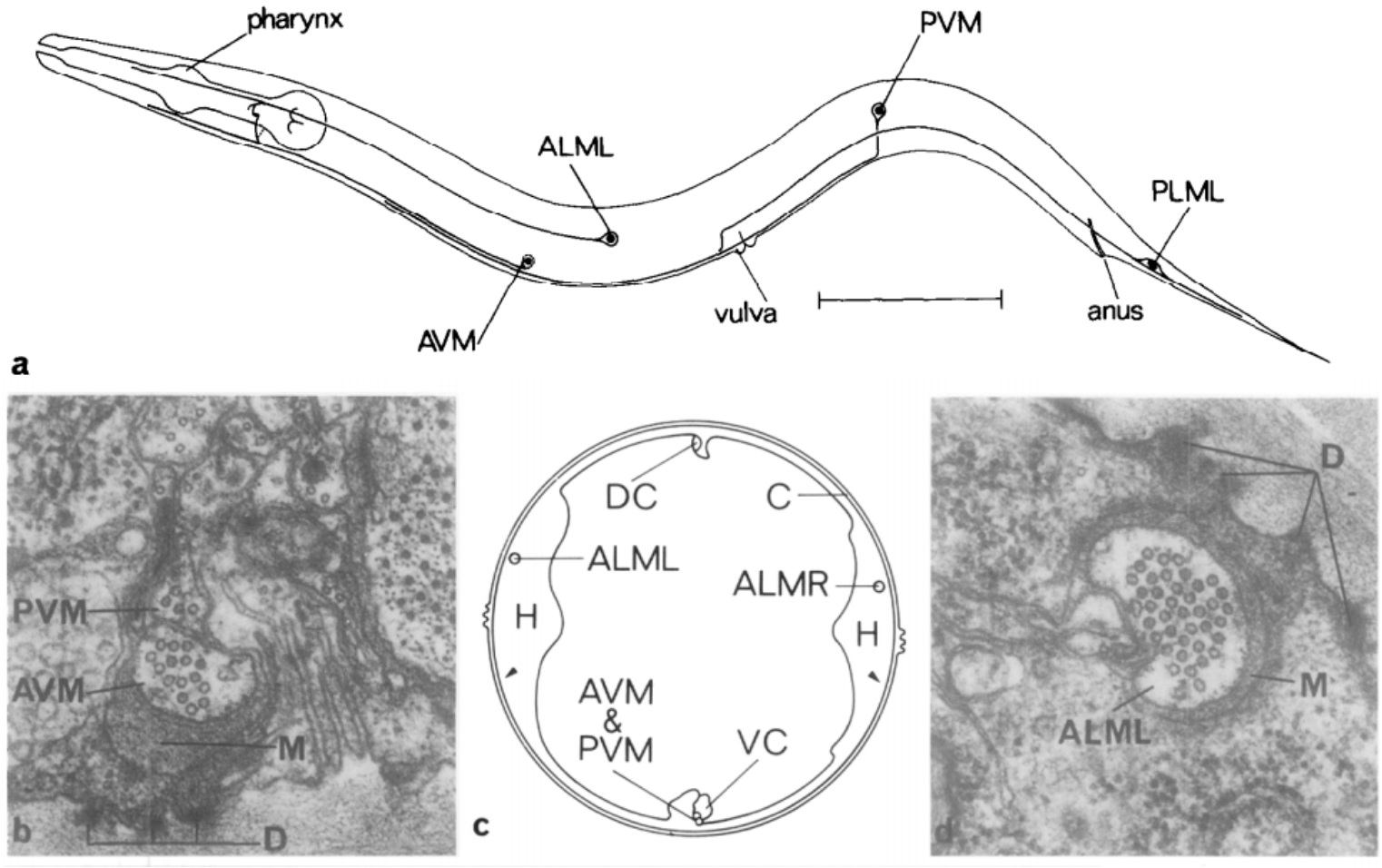
arrows indicate neurons

Fluorescent view:



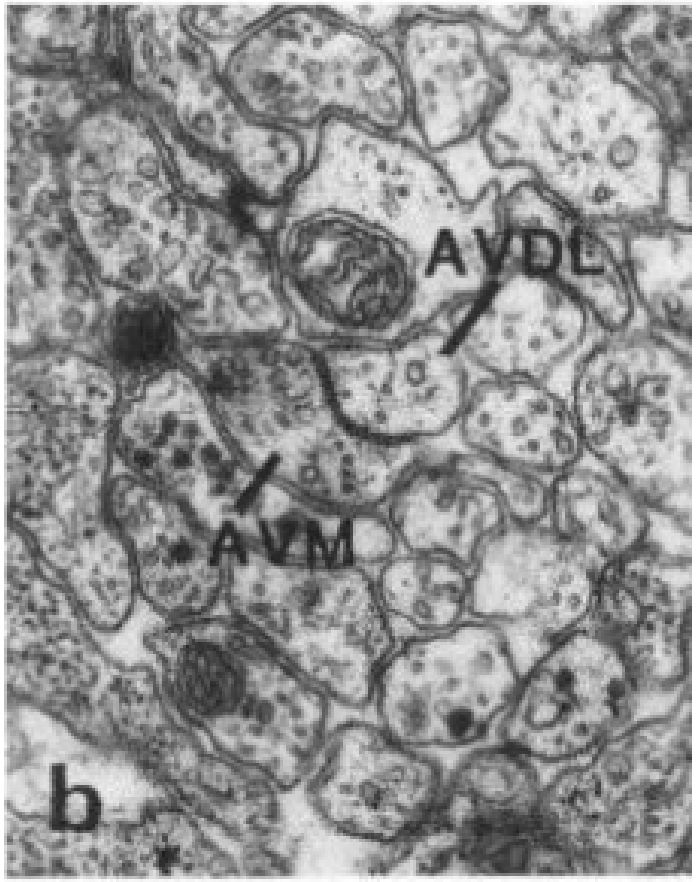
GFP specifically labels one of the neurons shown above

Anatomy of ALM, AVM and PLM neurons



Chalfie & Sulston 1981

Example of electrical synapse between AVM and AVD

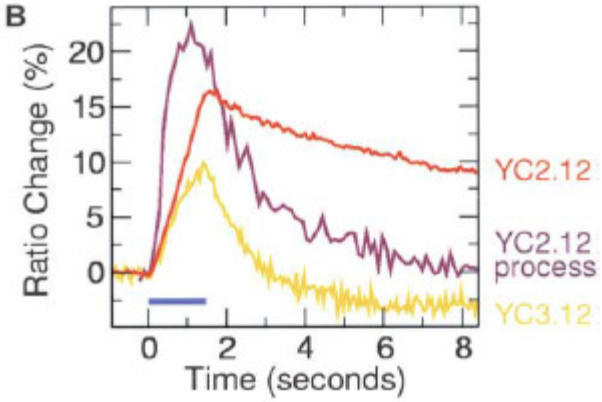


electrical

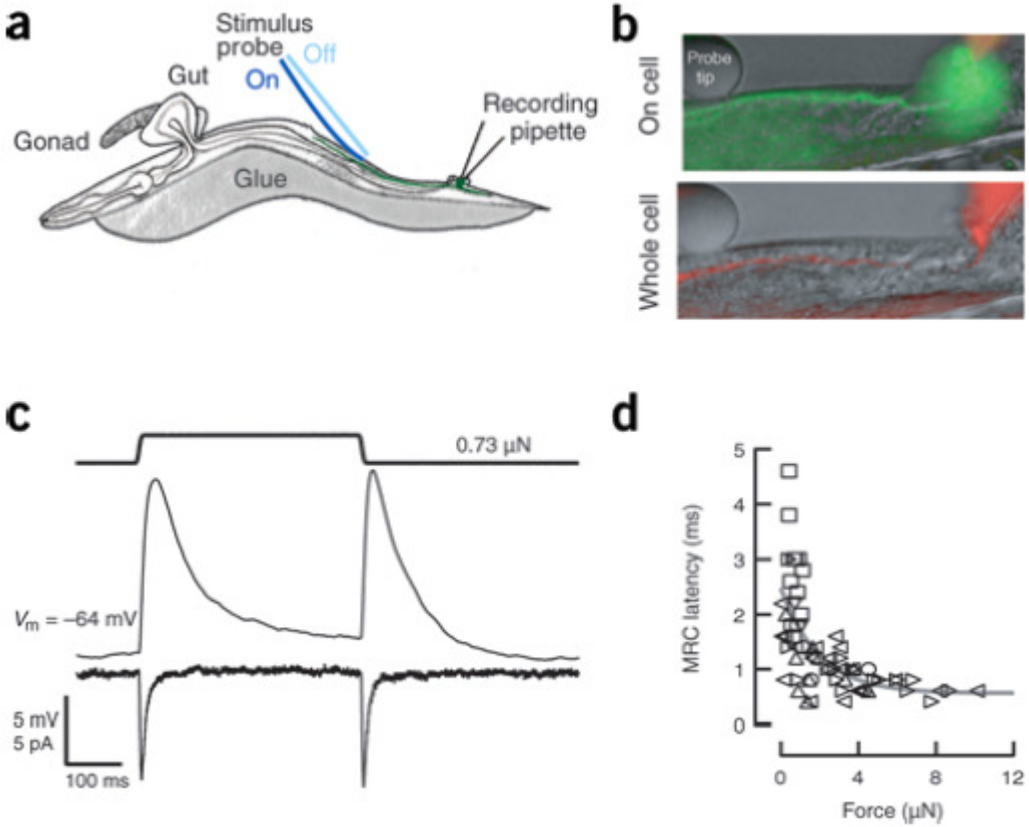
Chalfie..Brenner 1985

ALM and PLM respond to gentle touch

ALM

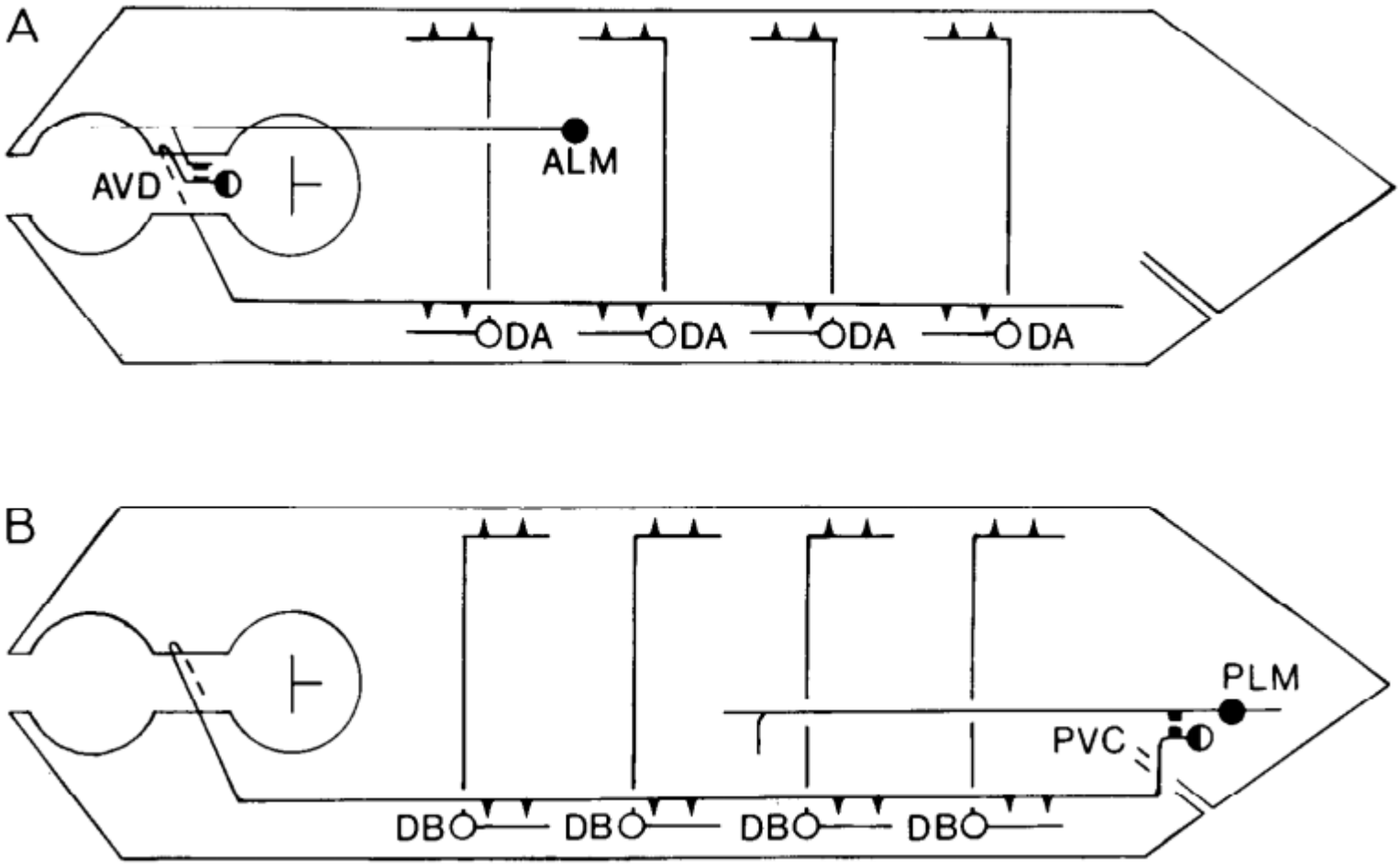


PLM



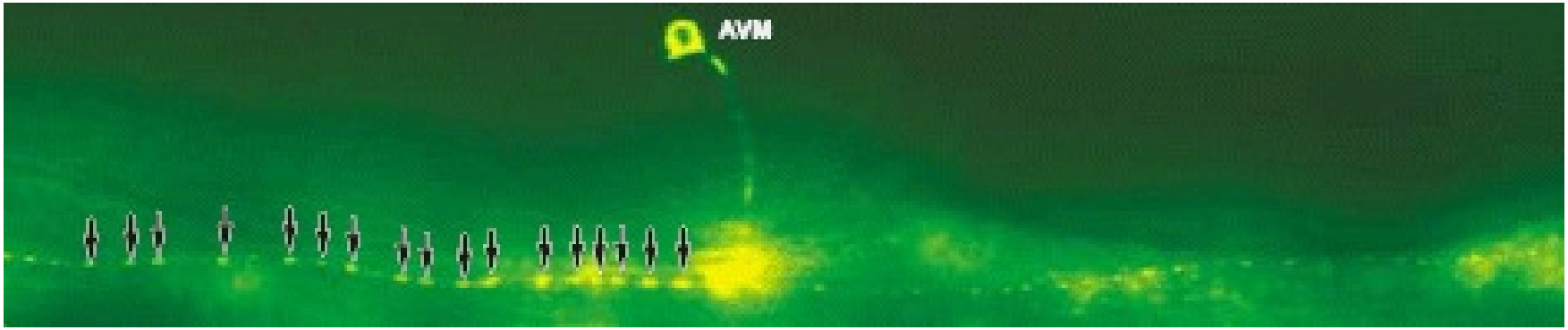
Suzuki..Schafer 2003, O'Hagan..Goodman 2005

Anatomical structure of gentle touch circuit



Chalfie..Brenner 1985

MEC-4 mechanosensory channel localizes to neurite of AVM



MEC-4::GFP localizes to puncta along AVM neurite

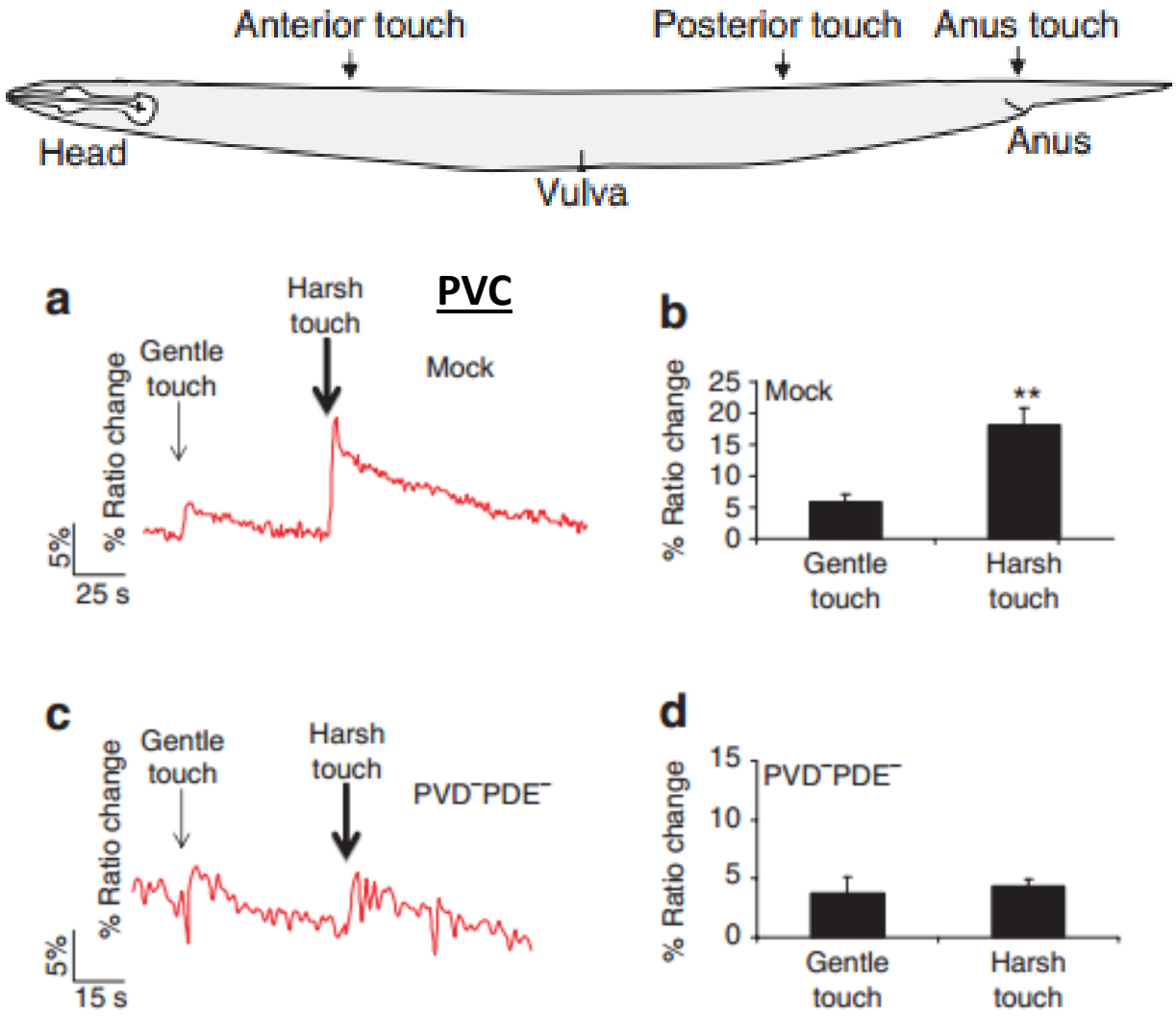
Voglis & Tavernarakis 2005

C. elegans reverses after anterior harsh touch

Video speed is real-time

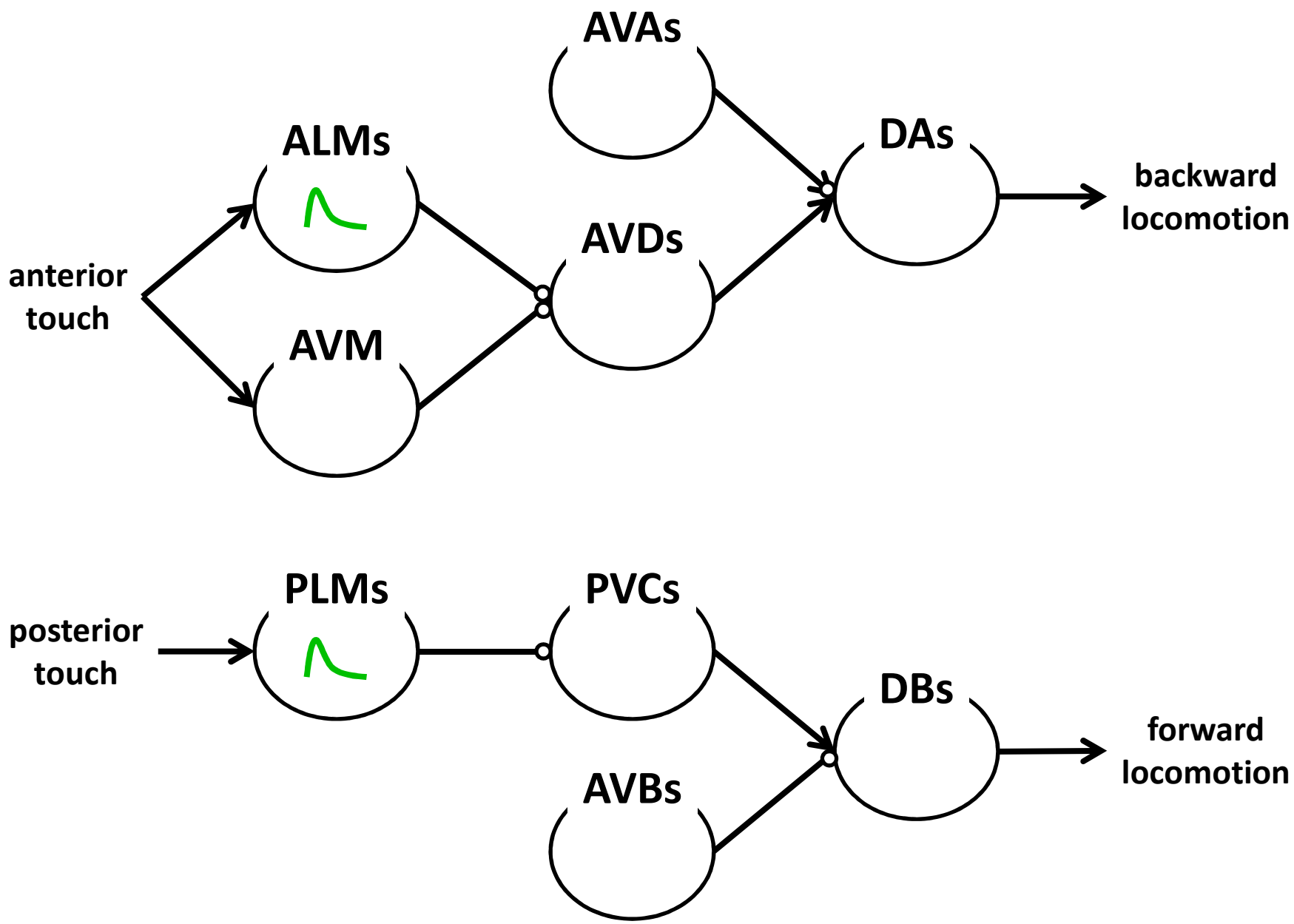
Li..Xu 2011

PVC neurons respond differently to gentle vs. harsh touch

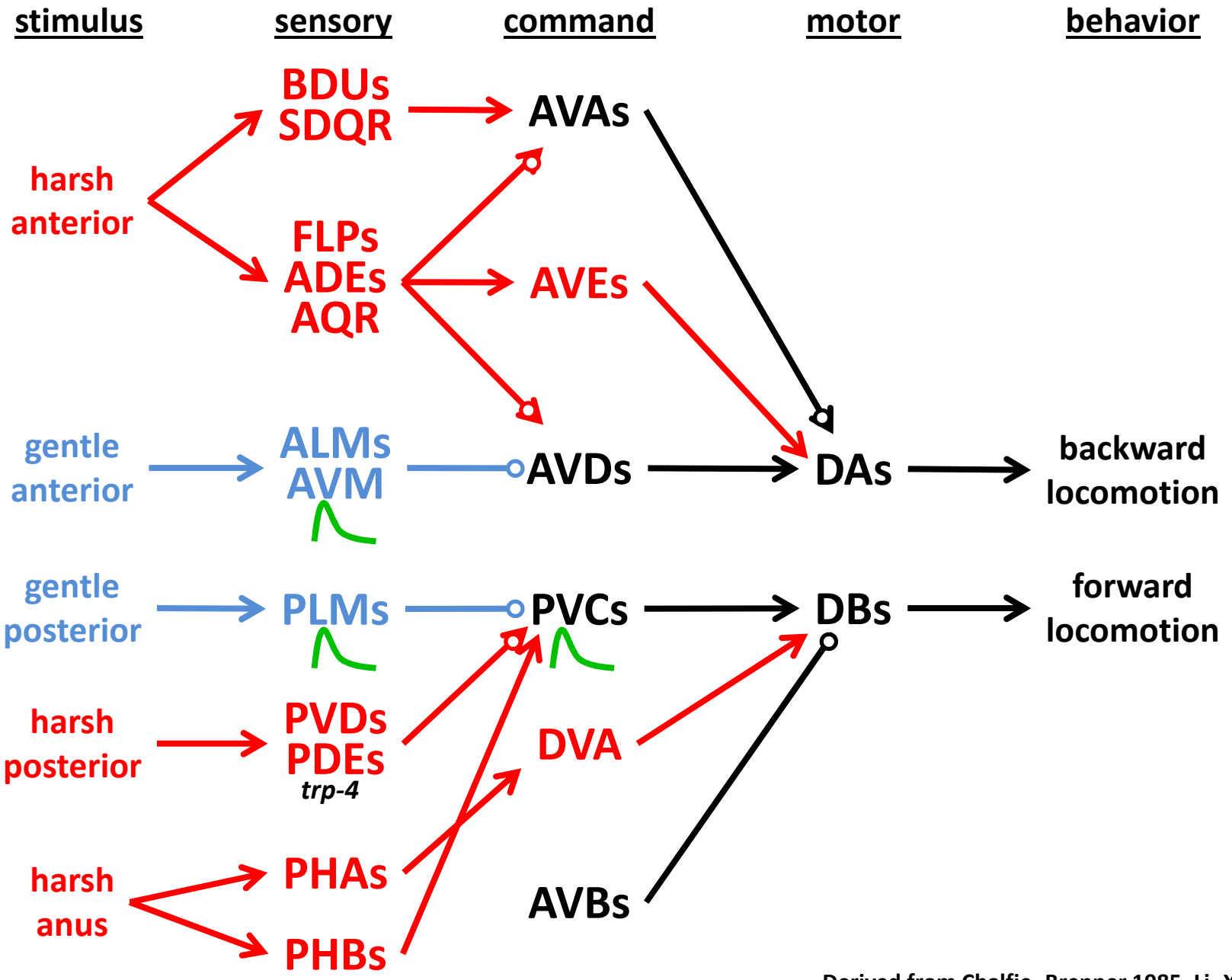


Li..Xu 2011

Circuit for gentle touch: excitatory mix of electrical and chemical synapse

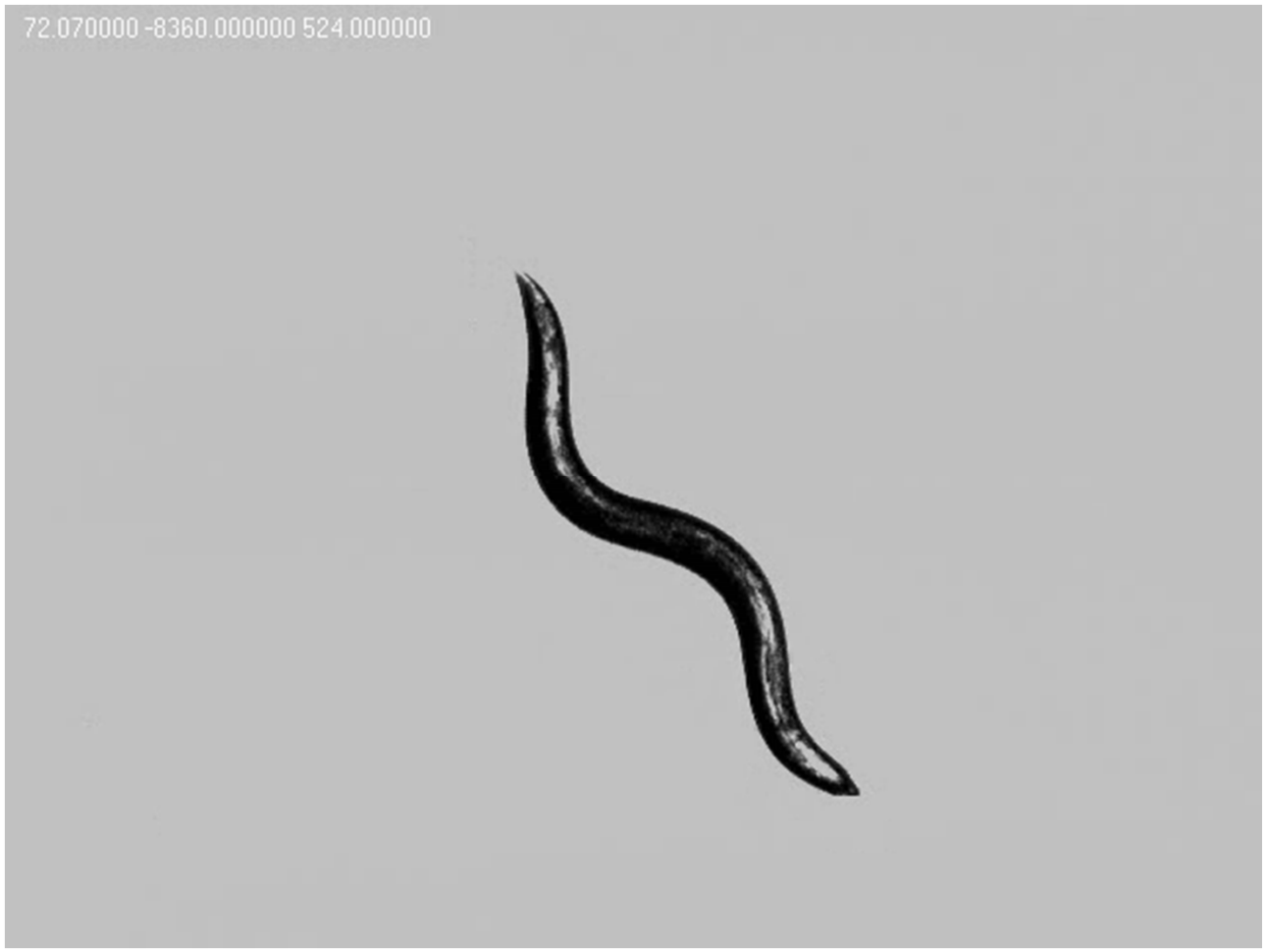


Circuit for touch-induced locomotion: gentle and harsh



Derived from Chalfie..Brenner 1985, Li..Xu 2011

C. elegans reverse in response to nose touch

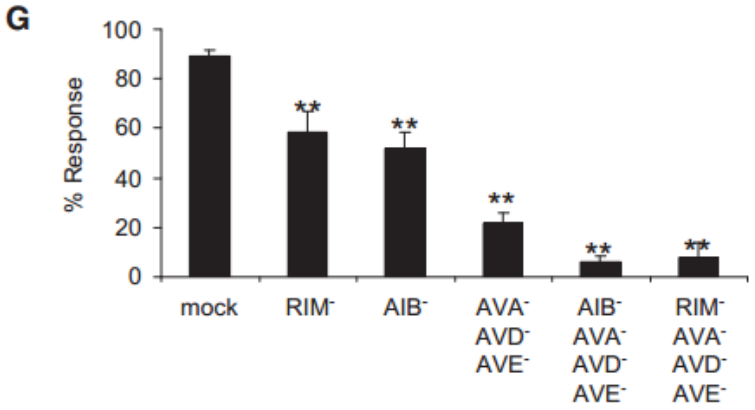


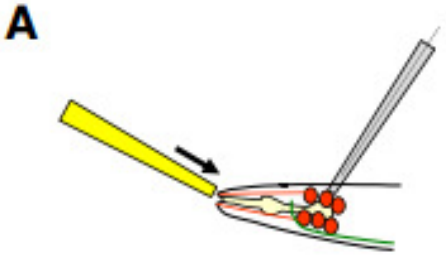
Video speed is real-time

Kindt..Schafer 2007

Nose touch depolarizes ASH and requires AVA, RIM and AIB

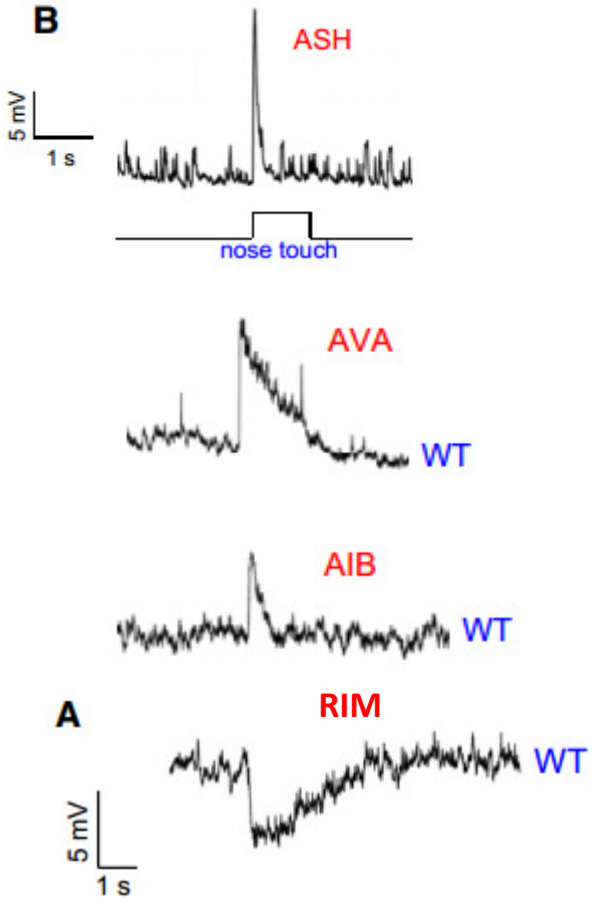
Ablations





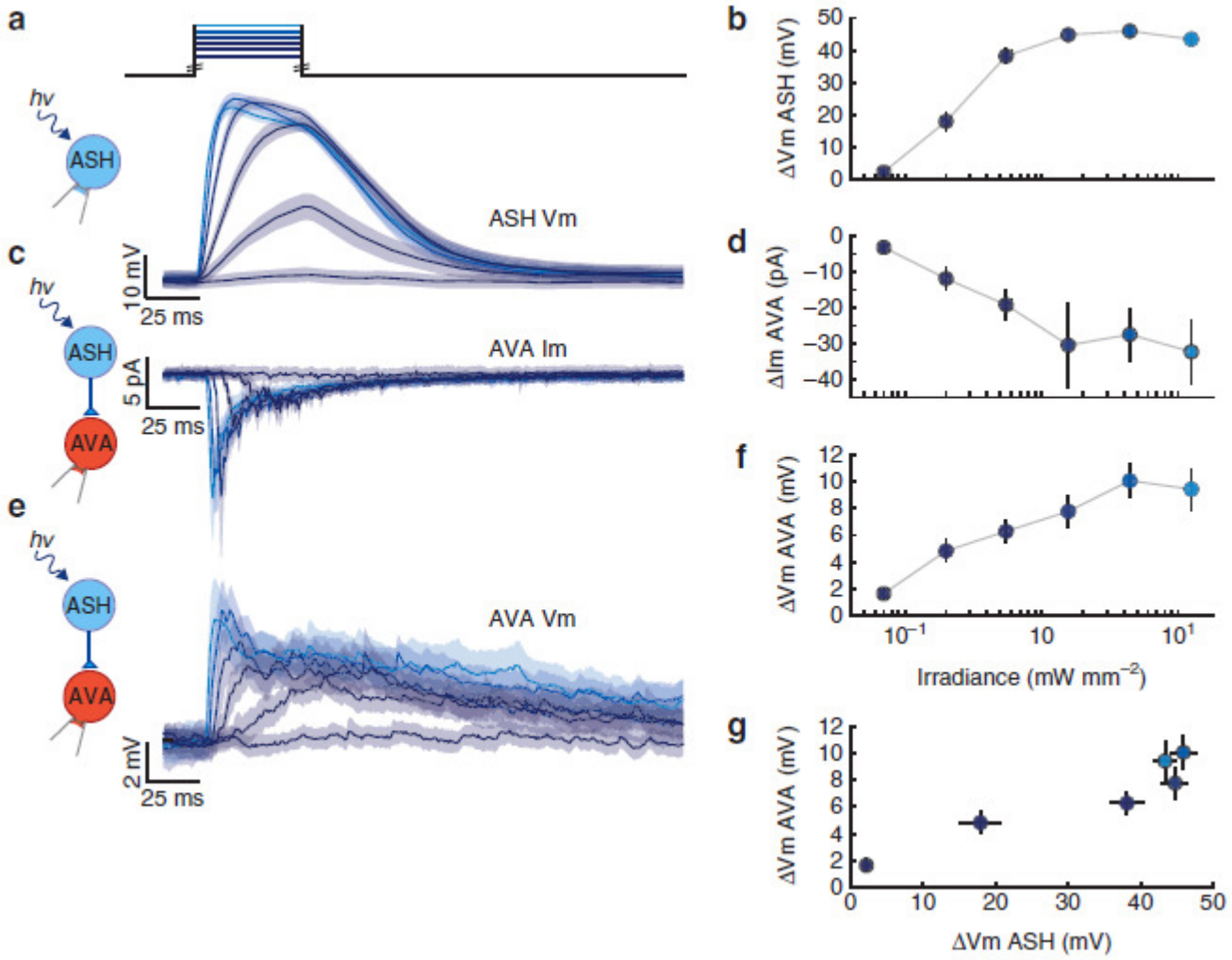
worm glued for electrophysiology

Physiology



Piggott..Xu 2011

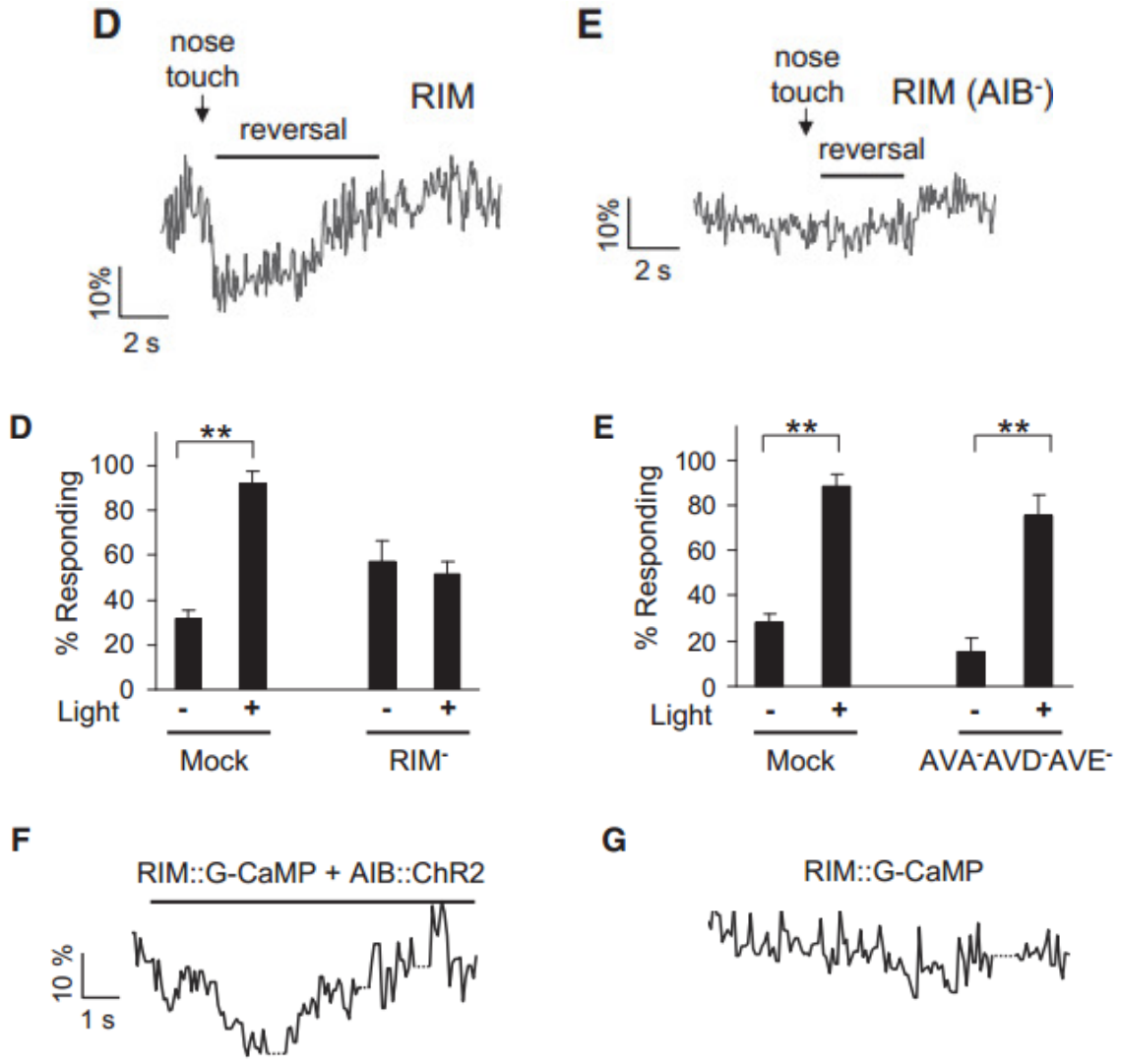
ASH activates AVA



Lindsay..Lockery 2011

Ordering the neurons into a circuit

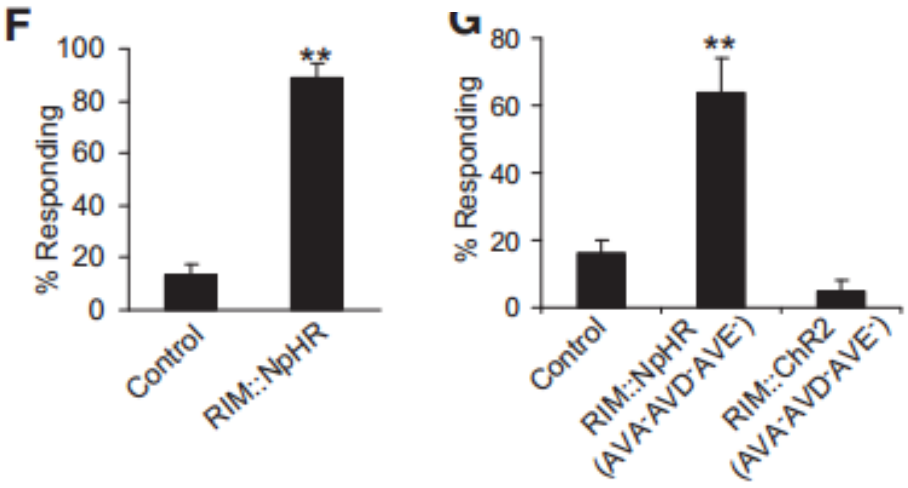
AIB is upstream of RIM and in parallel with AVA/D/E:



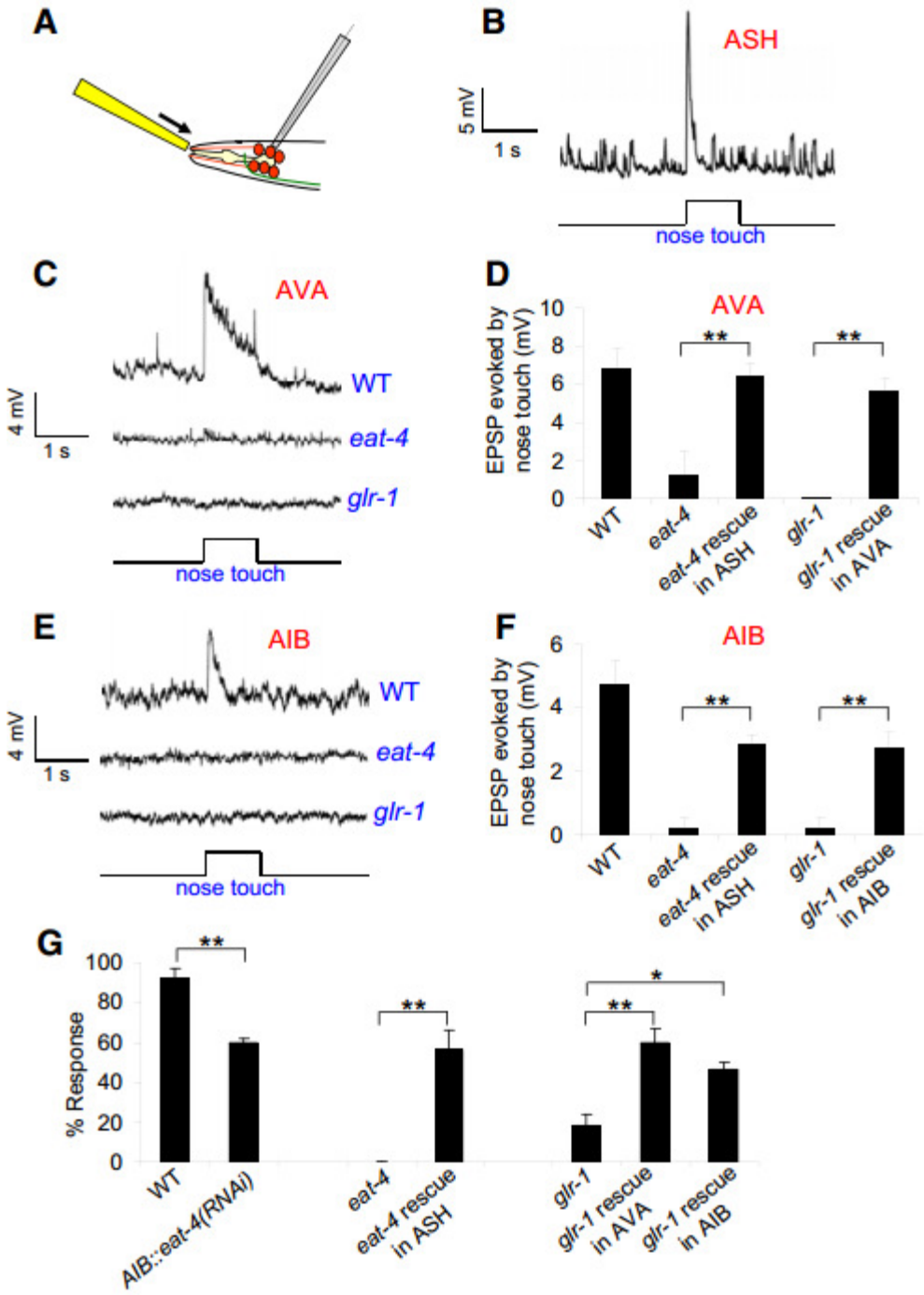
Piggott..Xu 2011

Ordering the neurons in the circuit

AVA and RIM are likely in parallel:



Piggott..Xu 2011

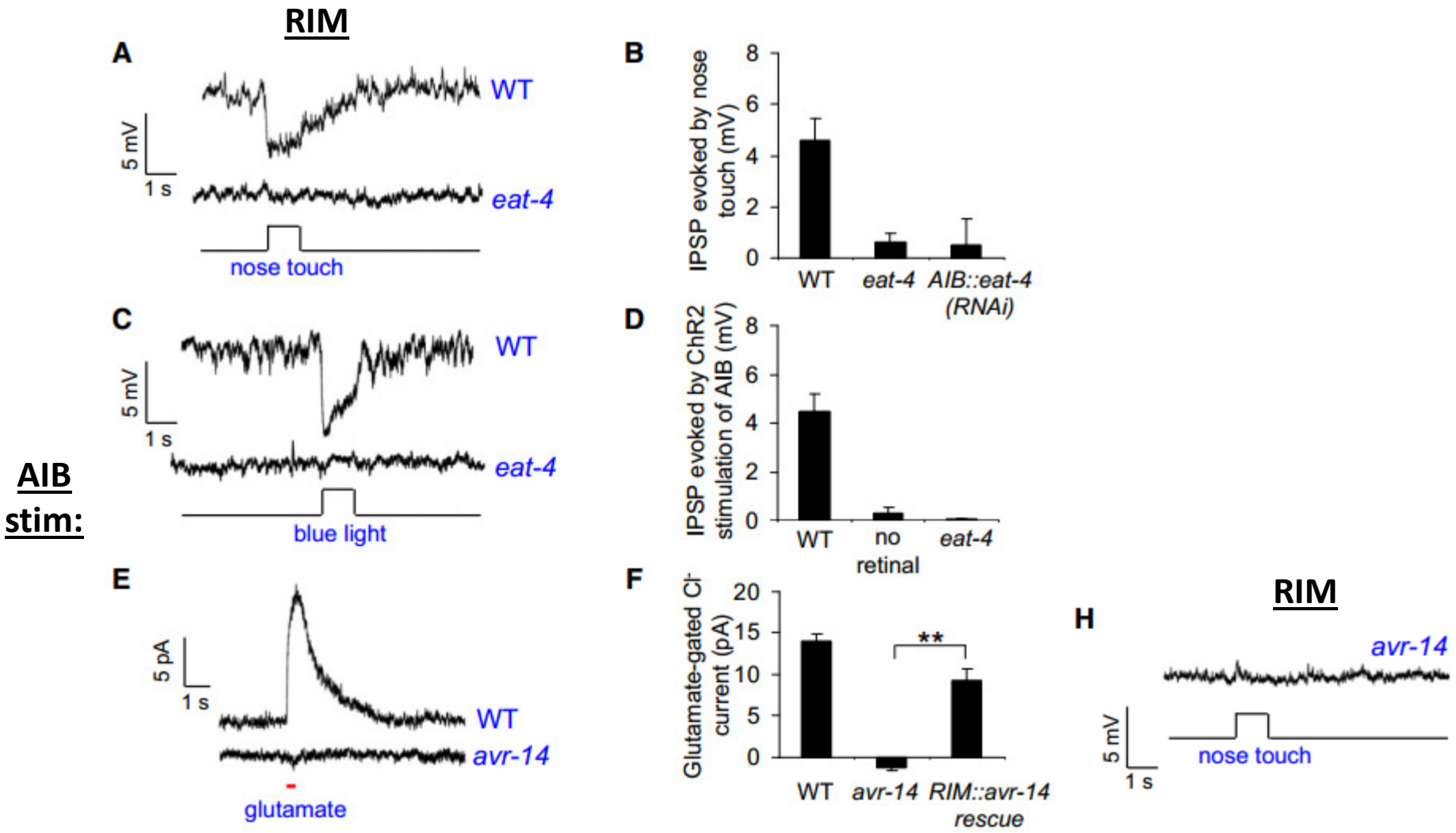


ASH releases glutamate onto AVA and AIB in response to nose touch

- **Post-synaptic glutamate receptor in AVA and AIB is *glr-1***

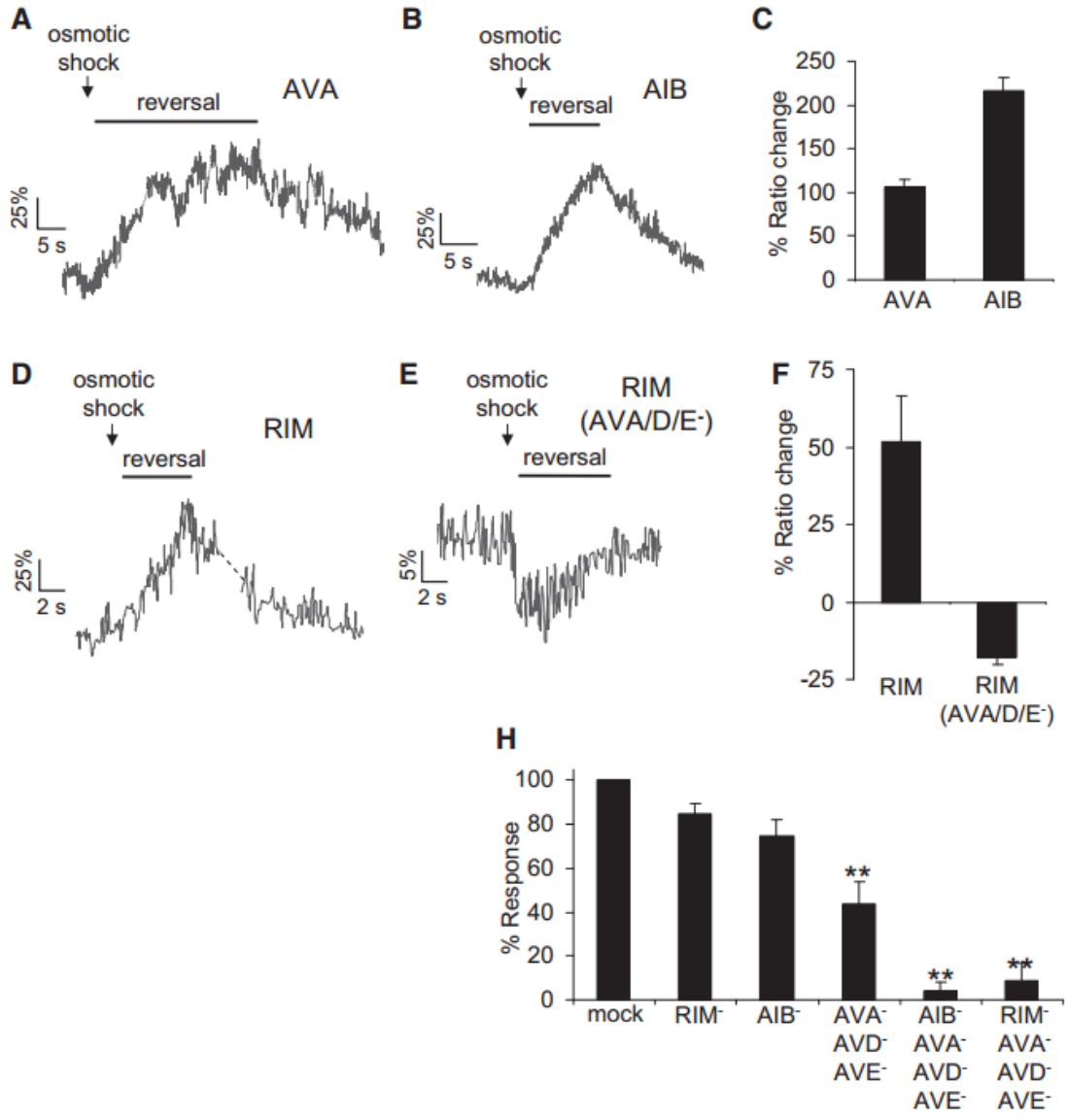
Piggott..Xu 2011

Nose touch stimulates AIB to release glutamate onto RIM



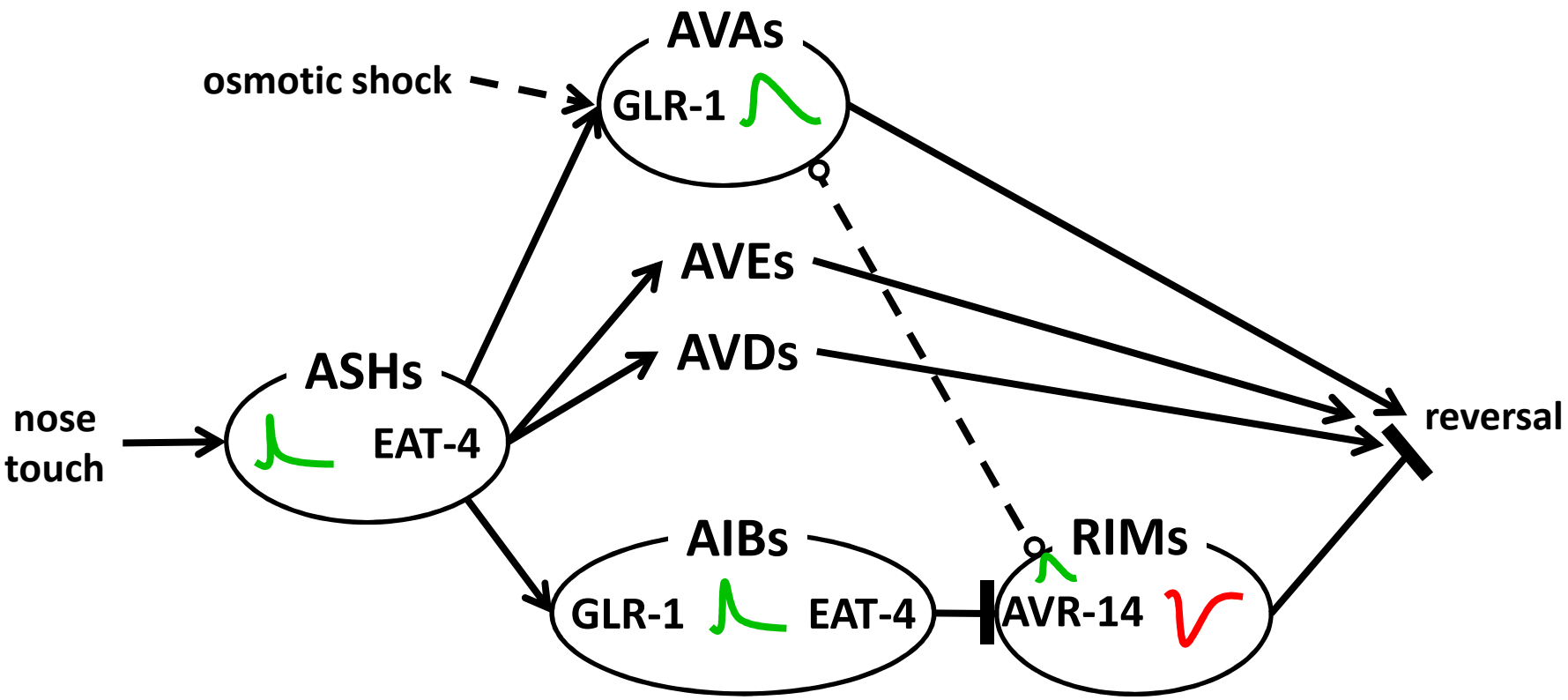
Piggott..Xu 2011

Osmotic shock is similar but different in its effect on RIM



Piggott..Xu 2011

Circuit for spontaneous and evoked reversals



Derived from Piggott..Xu 2011, Kaplan & Horvitz 1993

All connections between these 4 neurons (from the connectome)