Neural circuits for olfactory chemotaxis

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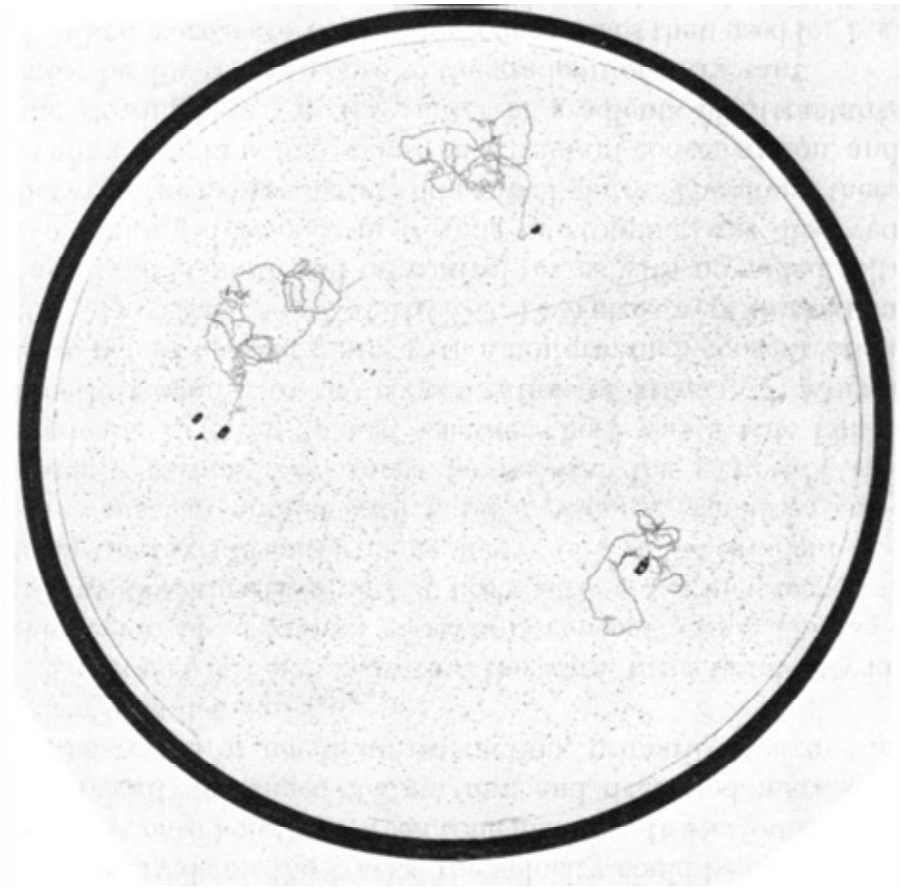
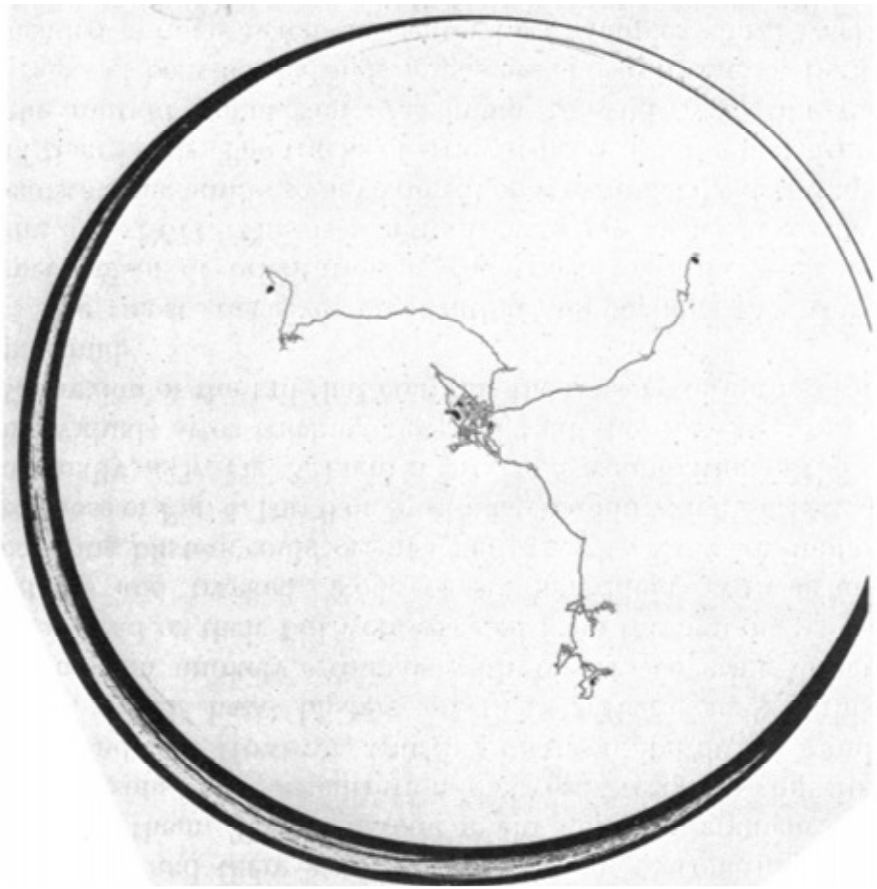
MIT IAP

C. elegans move to the peak of a chemical gradient (chemotaxis)



3 worms explore without chemical gradient

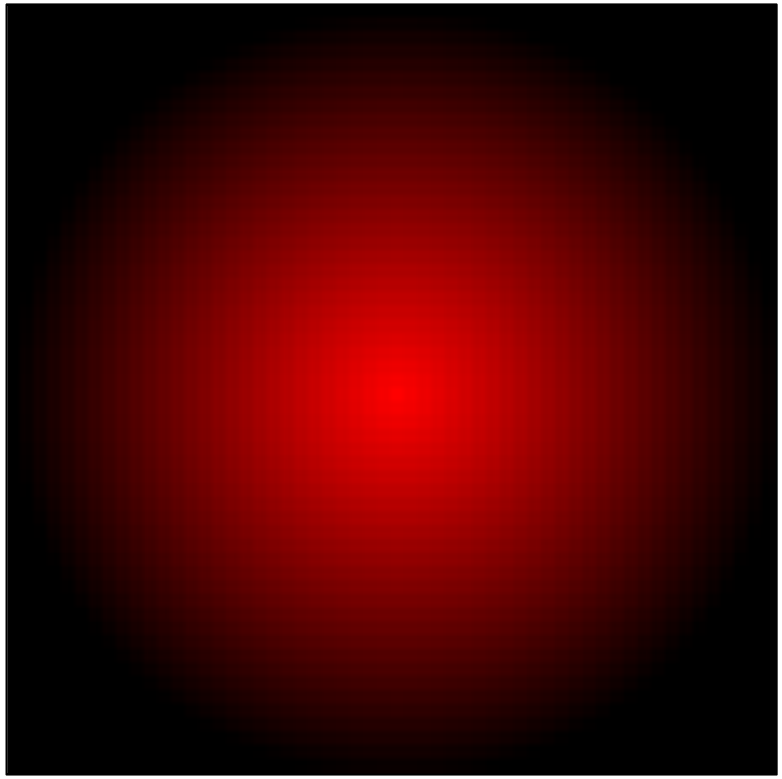


3 worms explore with chemical gradient (peak at center)

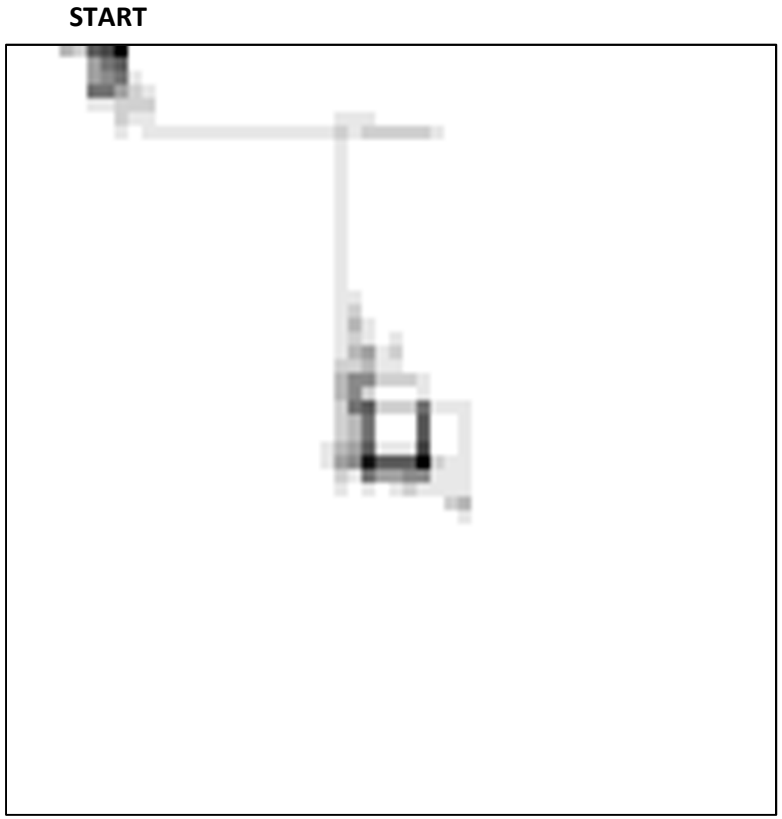
15 min tracks
Attracting is chloride ions

Ward 1973

Directed movement by klinokinesis (aka ‘biased random walk’)



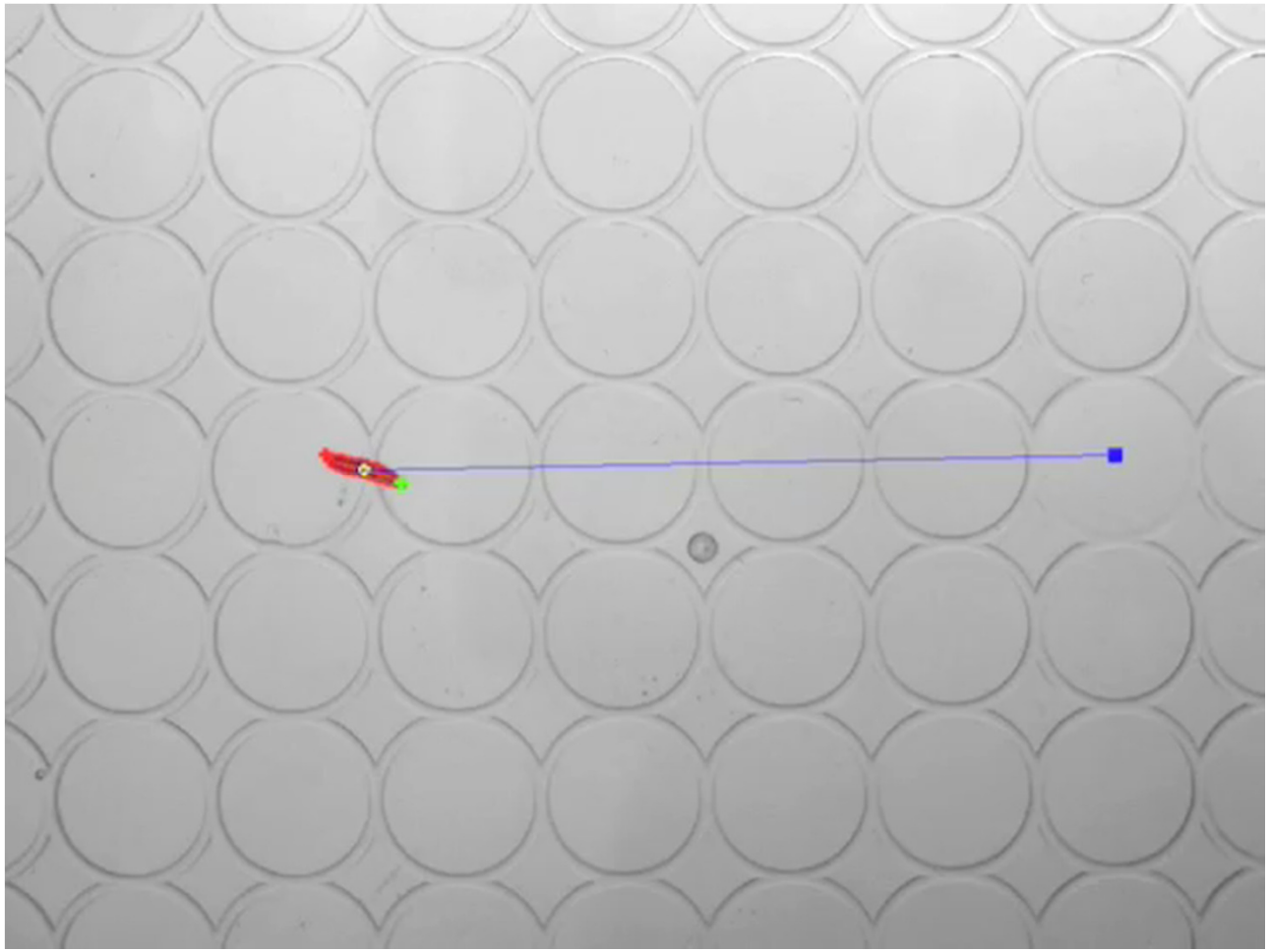
Attractant gradient



Simulated bacterium’s path

Simulation result from Bacterial Chemotaxis Simulator: wormweb.org/bacteriachemo

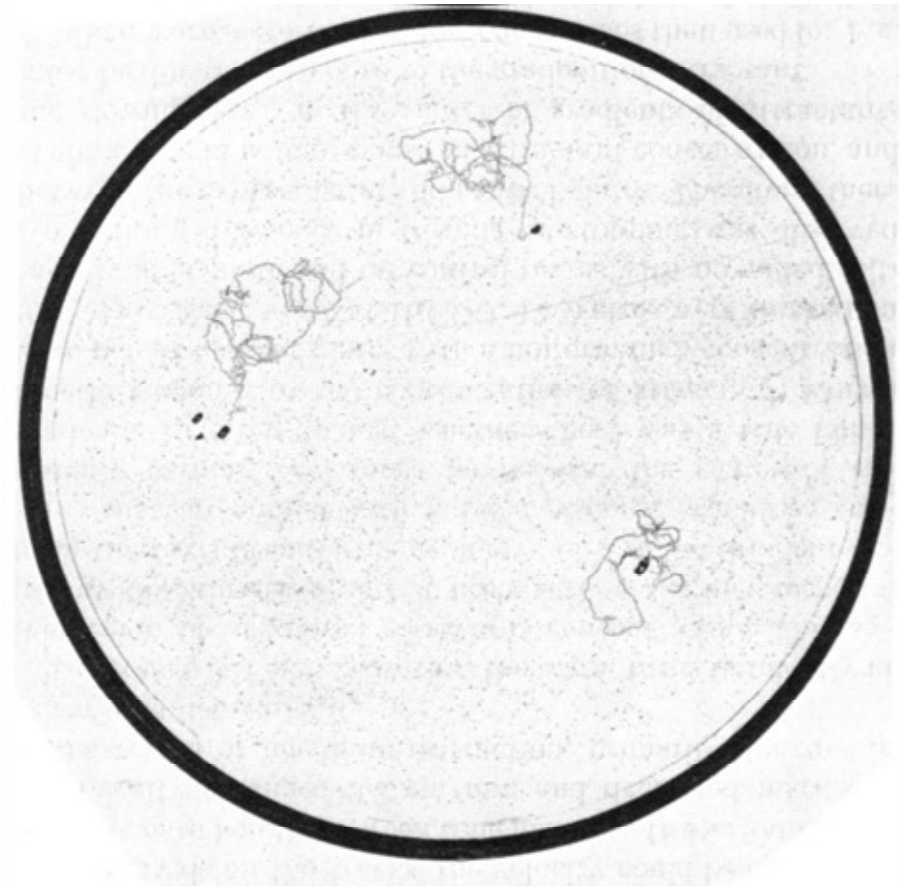
Directed movement by klinotaxis (aka ‘weathervane’)



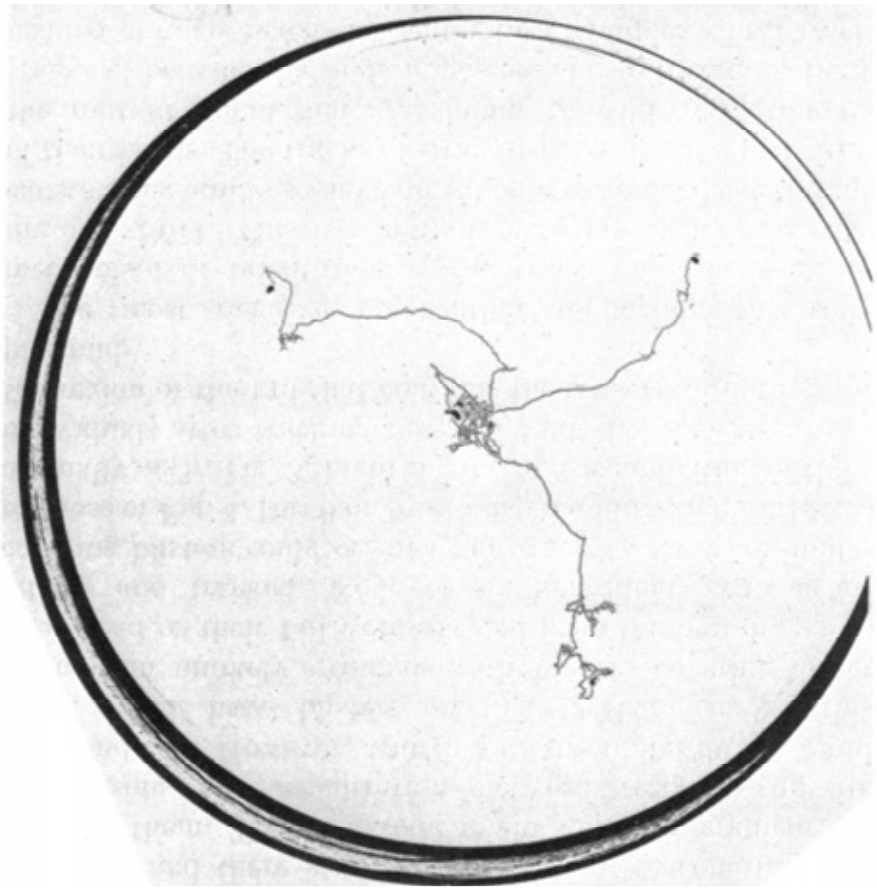
Drosophila larvae

Gomez-Marin..Louis 2011

C. elegans move to the peak of a chemical gradient (chemotaxis)



3 worms explore without chemical gradient



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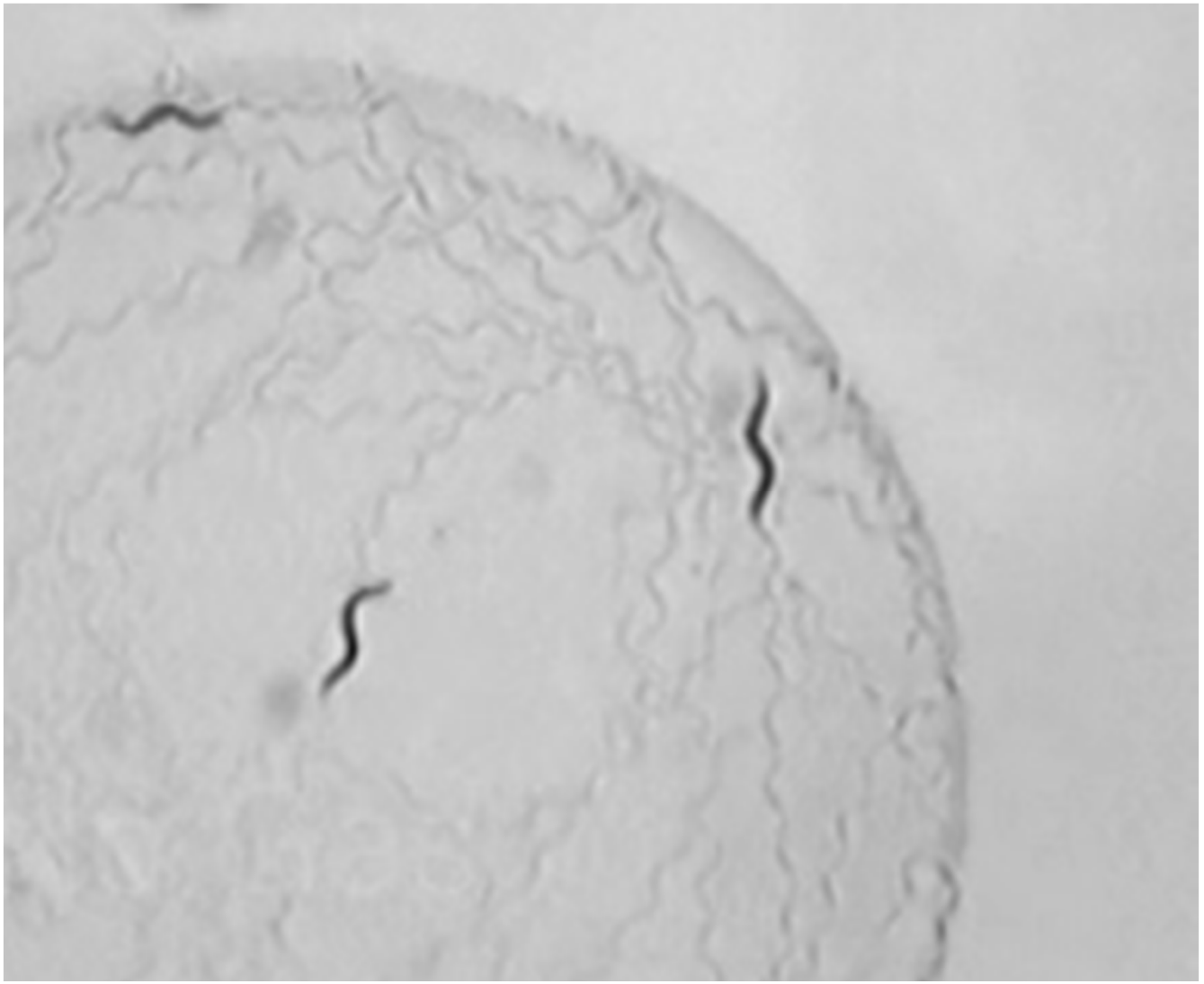
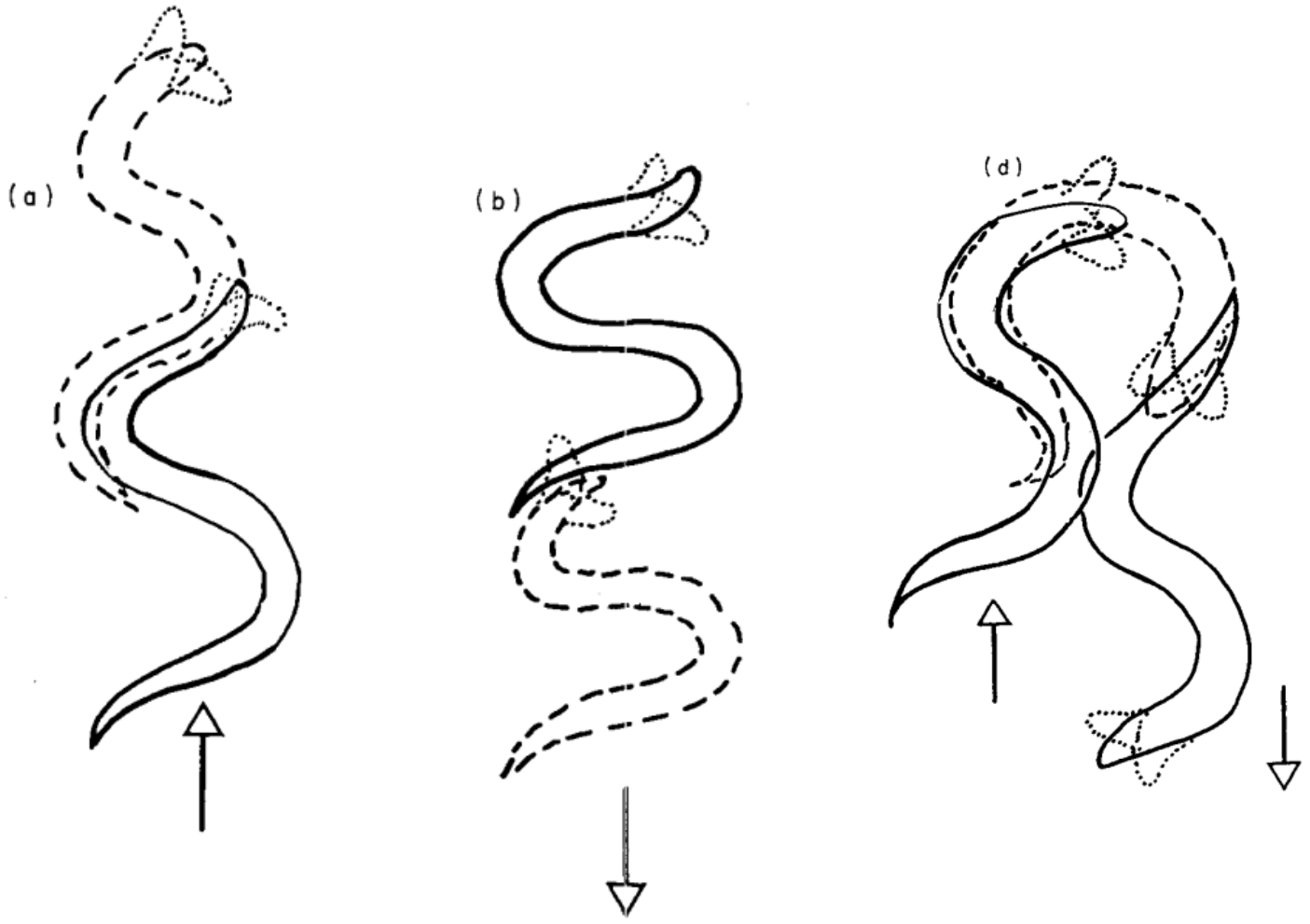
C. elegans locomotion patterns



Cheung..de Bono 2005

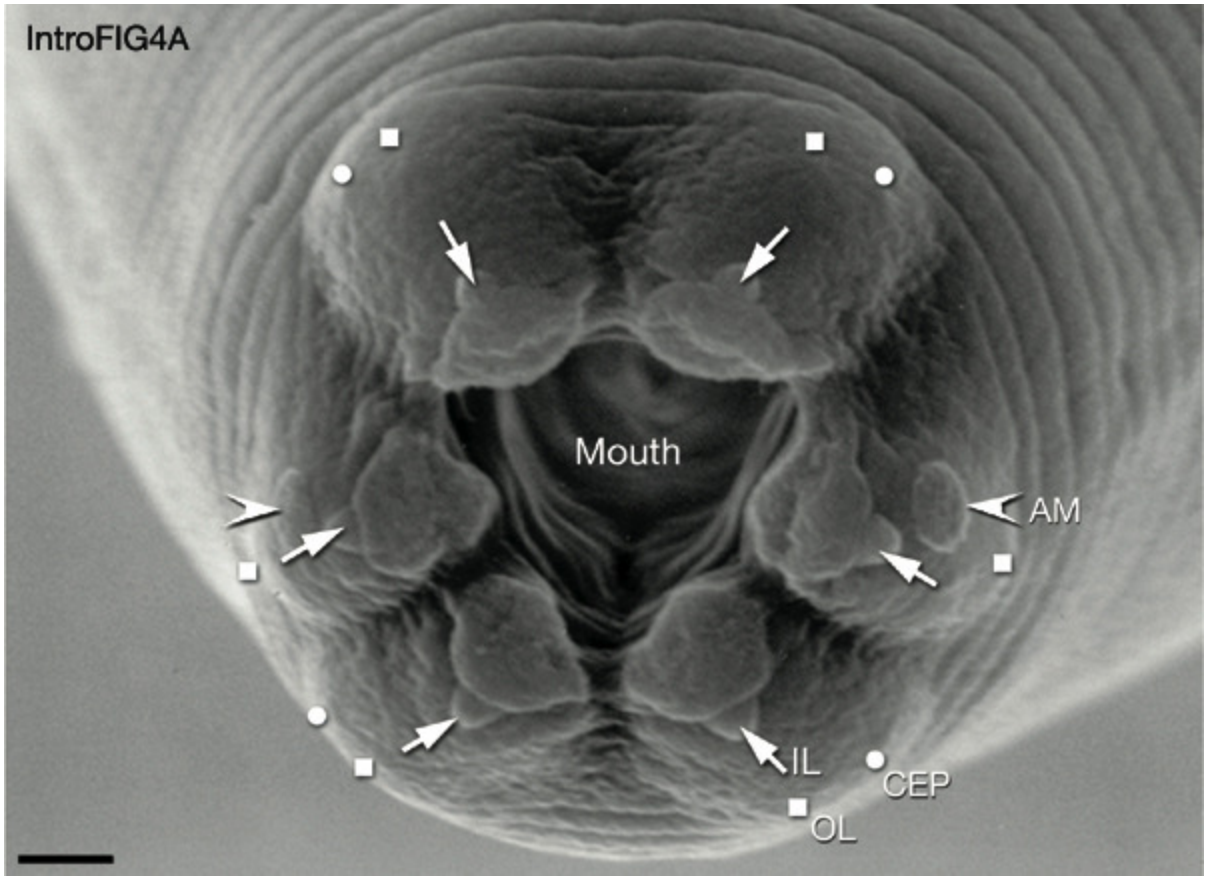
C. elegans locomotion patterns



forward **backward** **omega turn**

Croll 1975

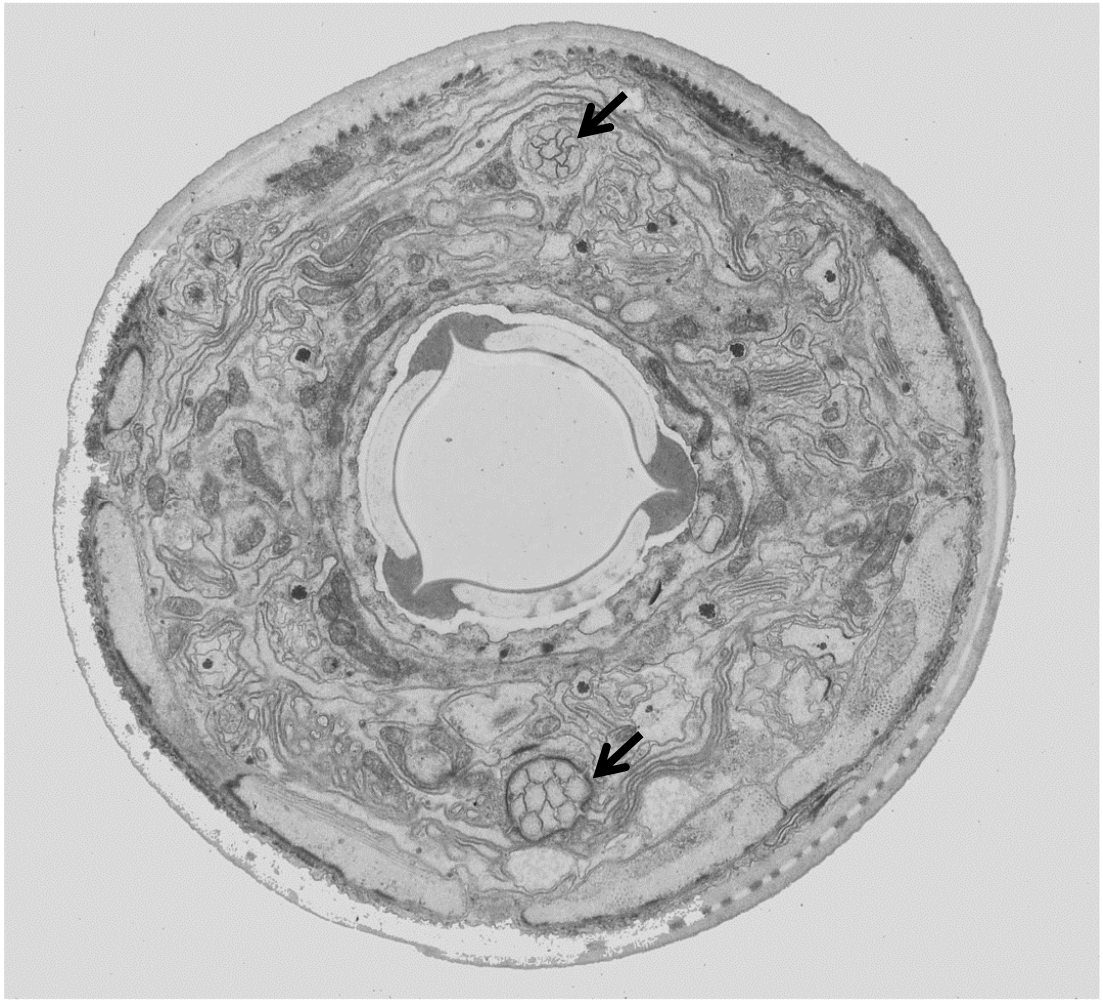
Head Sensilla



AM = amphid (12 neurons x 2)
IL = inner labia (2 neurons x 6)
OL = outer labia (1 neuron x 6)
CEP = cephalic (1 neuron x 4)

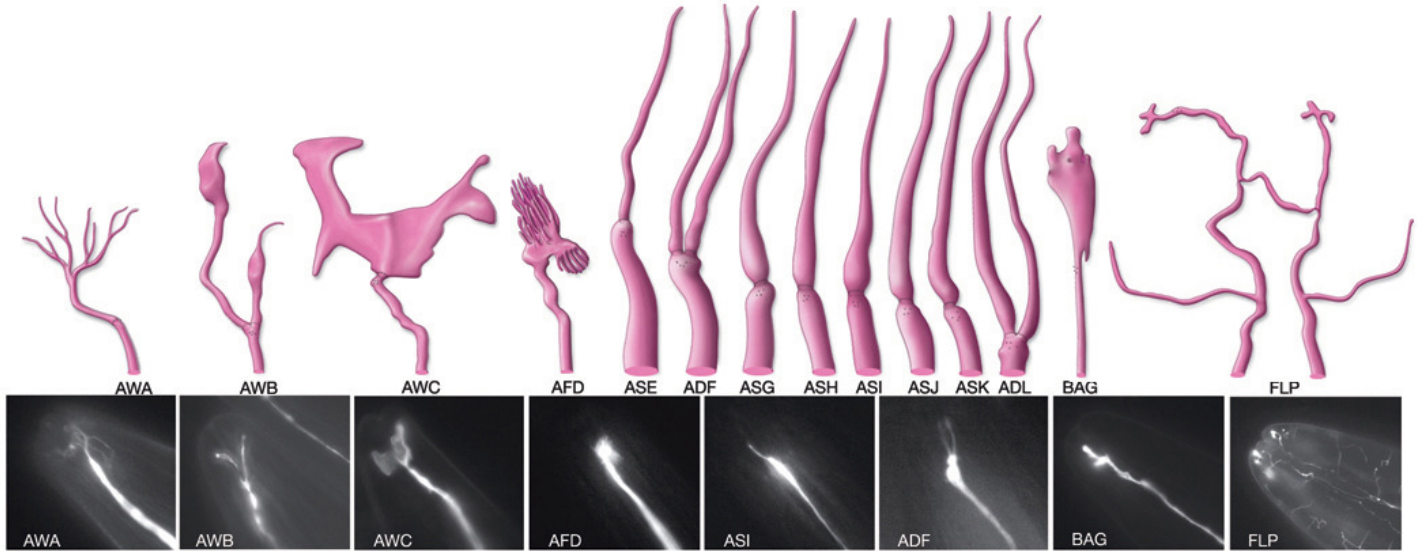
WormAtlas.org

Amphids

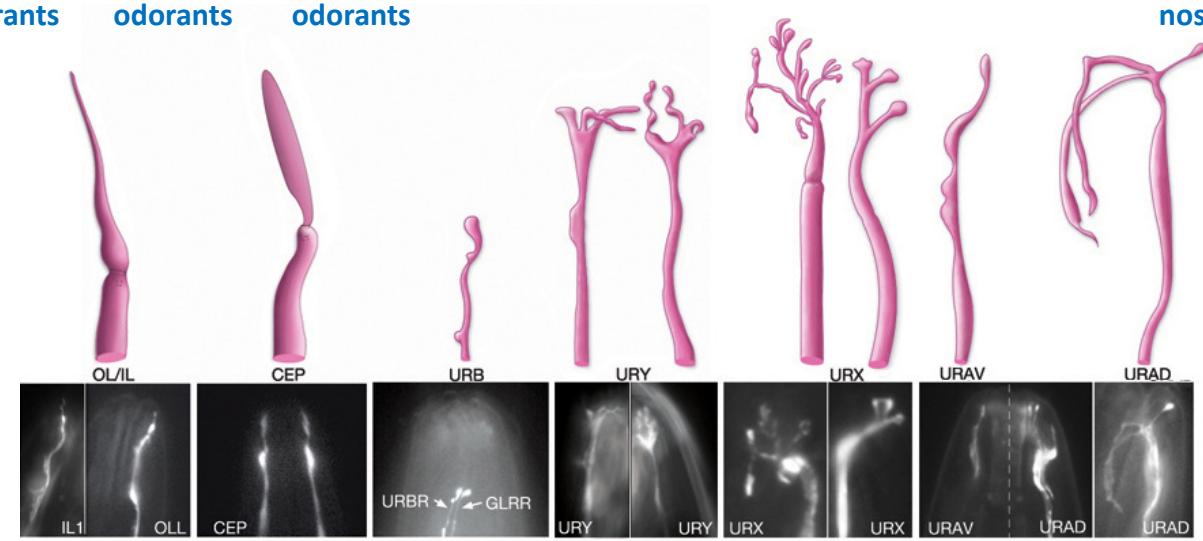


Cross section at tip of nose

Head sensory neuron cilia



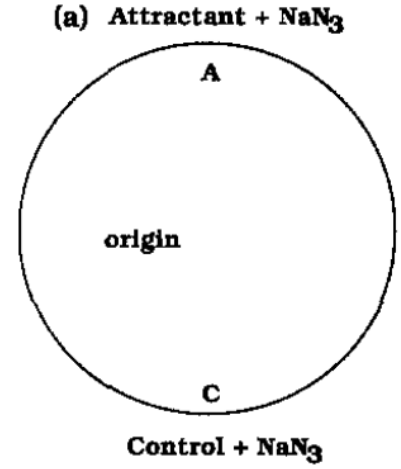
Senses: attractive odorants | repulsive odorants | attractive odorants | temp. | pheromones | salt | O_2 & CO_2 | harsh touch nose touch



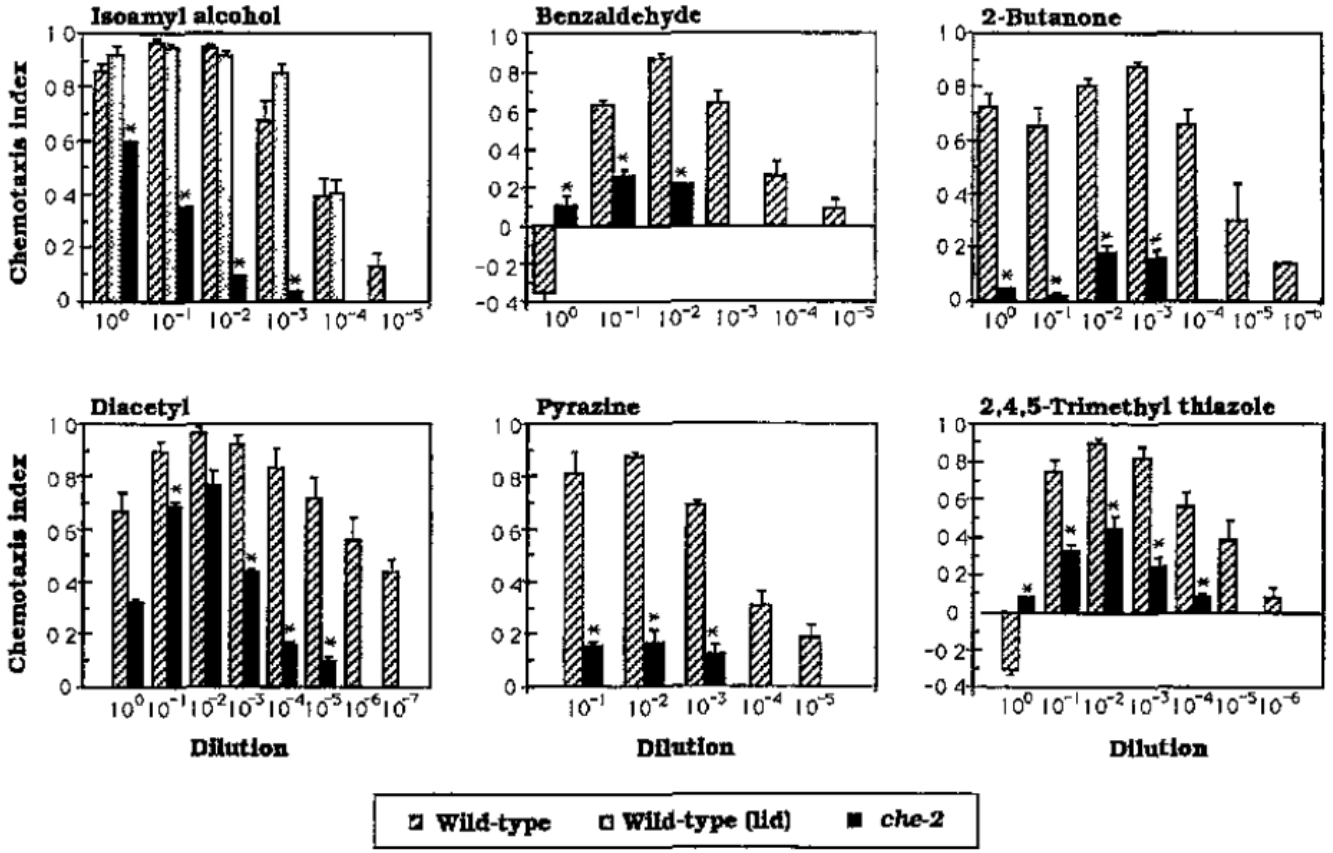
Senses: nose touch | food shape? | ? | mating cue? | O_2 | ? | ?

WormAtlas.org

Worms are attracted to various odorants



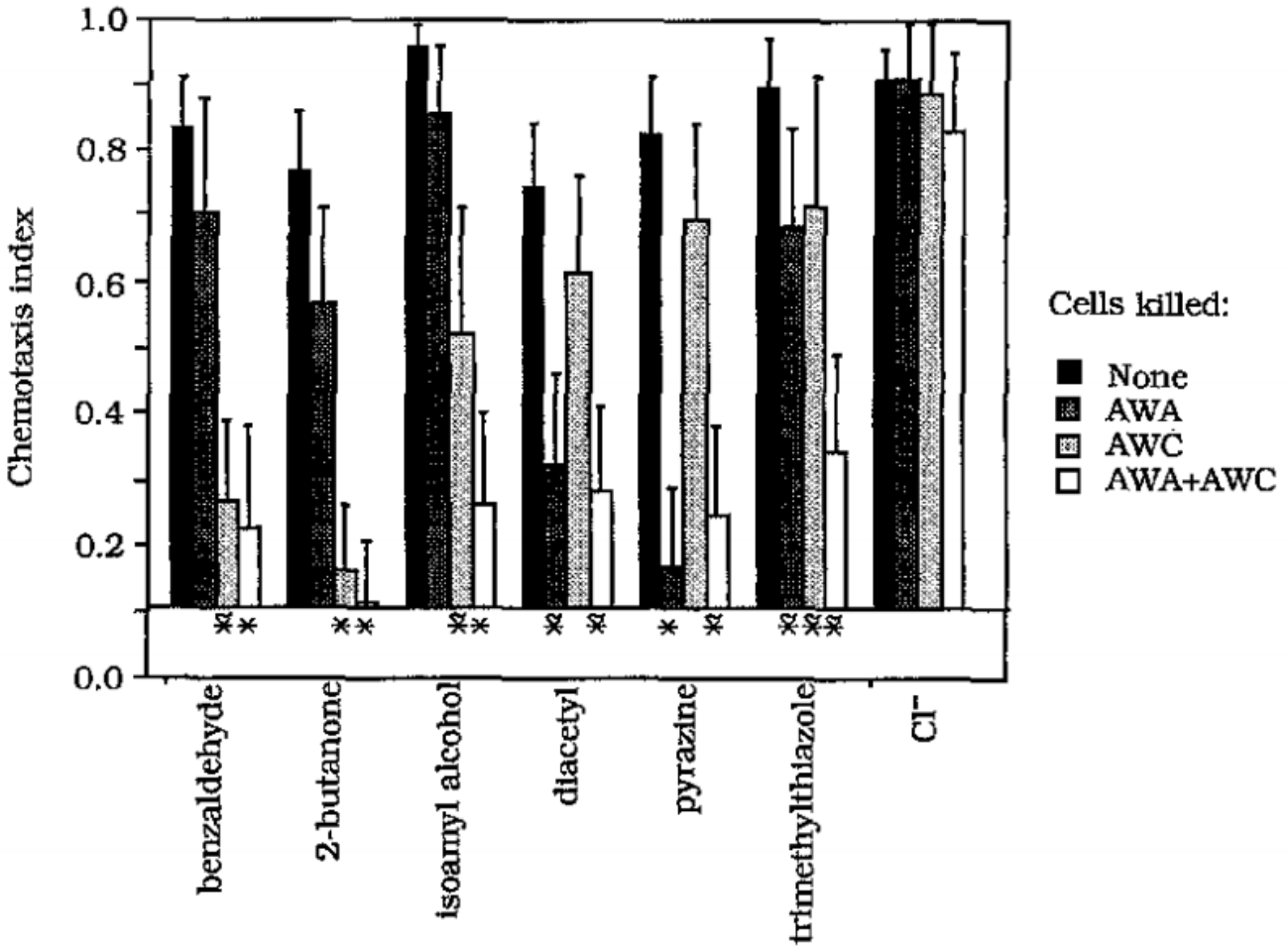
$$\text{Chemotaxis index} = \frac{\#A - \#C}{\#\ \text{total}}$$



che-2 **is required for cilia formation**

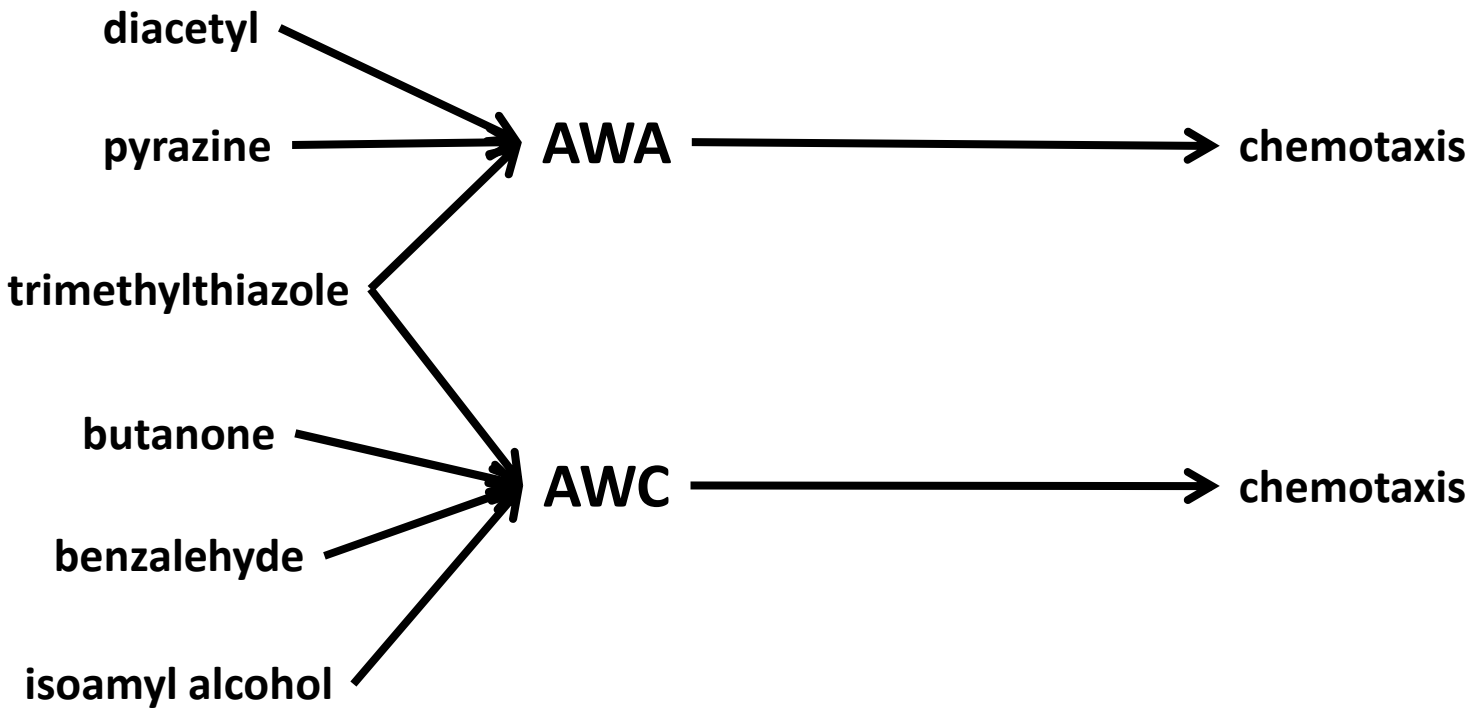
Bargmann..Horvitz 1993

AWA and AWC are involved in sensing mostly different odorants



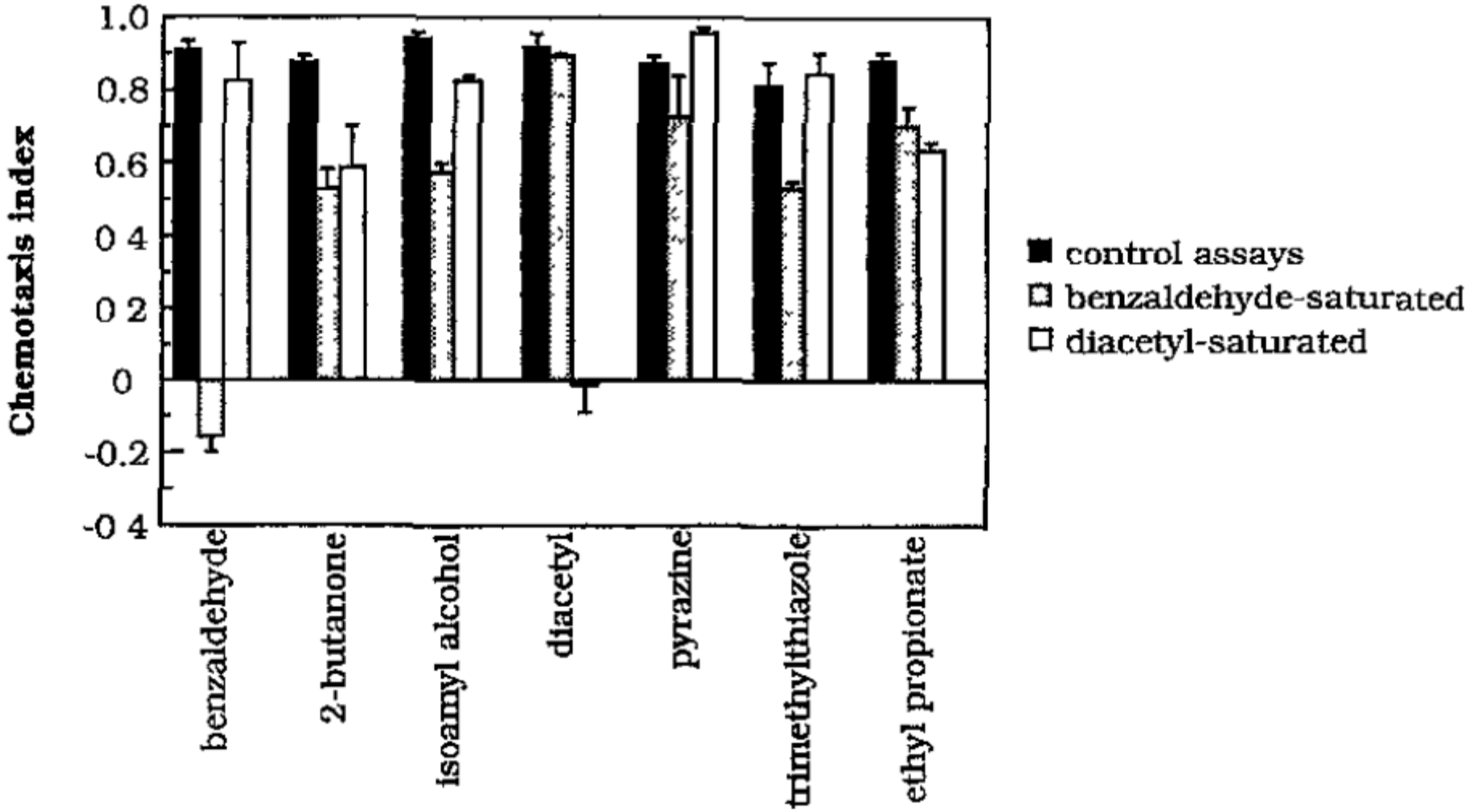
Bargmann..Horvitz 1993

Sensors for chemoattractants



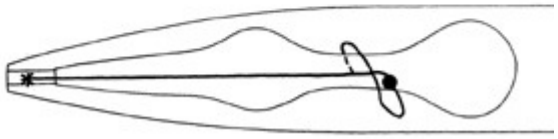
Derived from Bargmann..Horvitz 1993

Worms can distinguish odorants smelled by the same sensory neuron

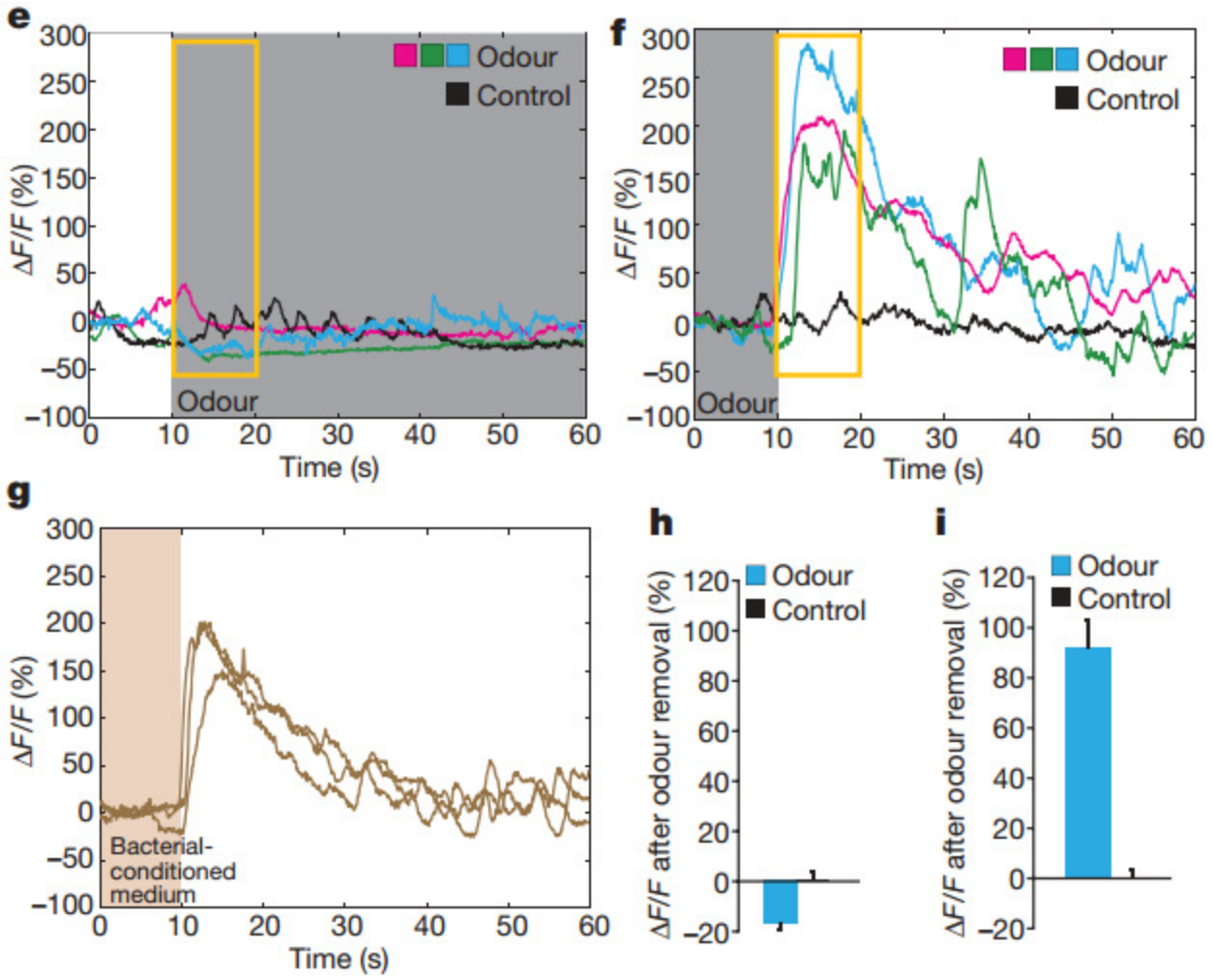


Bargmann..Horvitz 1993

AWC responds most strongly to IA and food removal

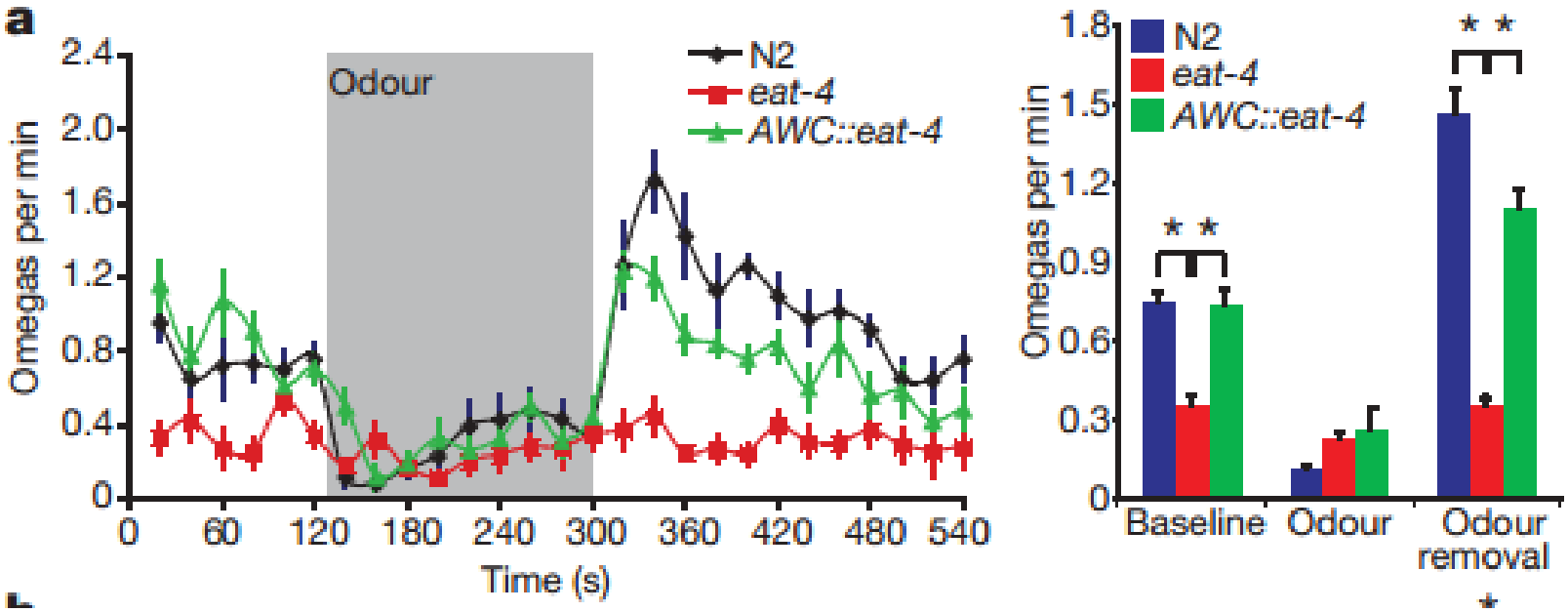


AWC



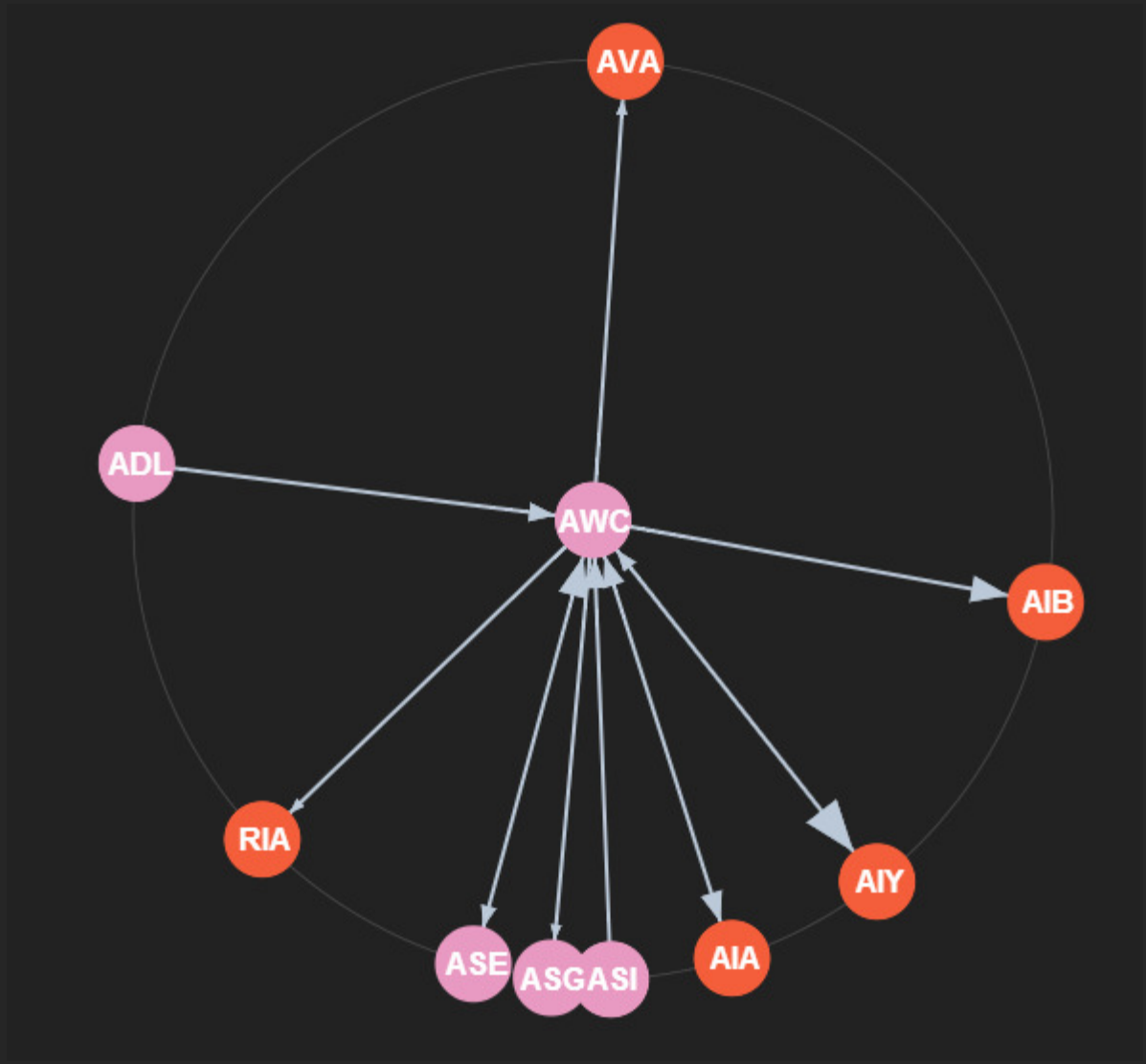
Chalasani..Bargmann 2007

AWC activity correlates with omega turns



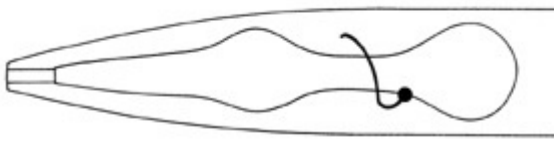
Chalasani..Bargmann 2007

AWC primarily outputs to AIY, AIB and AIA

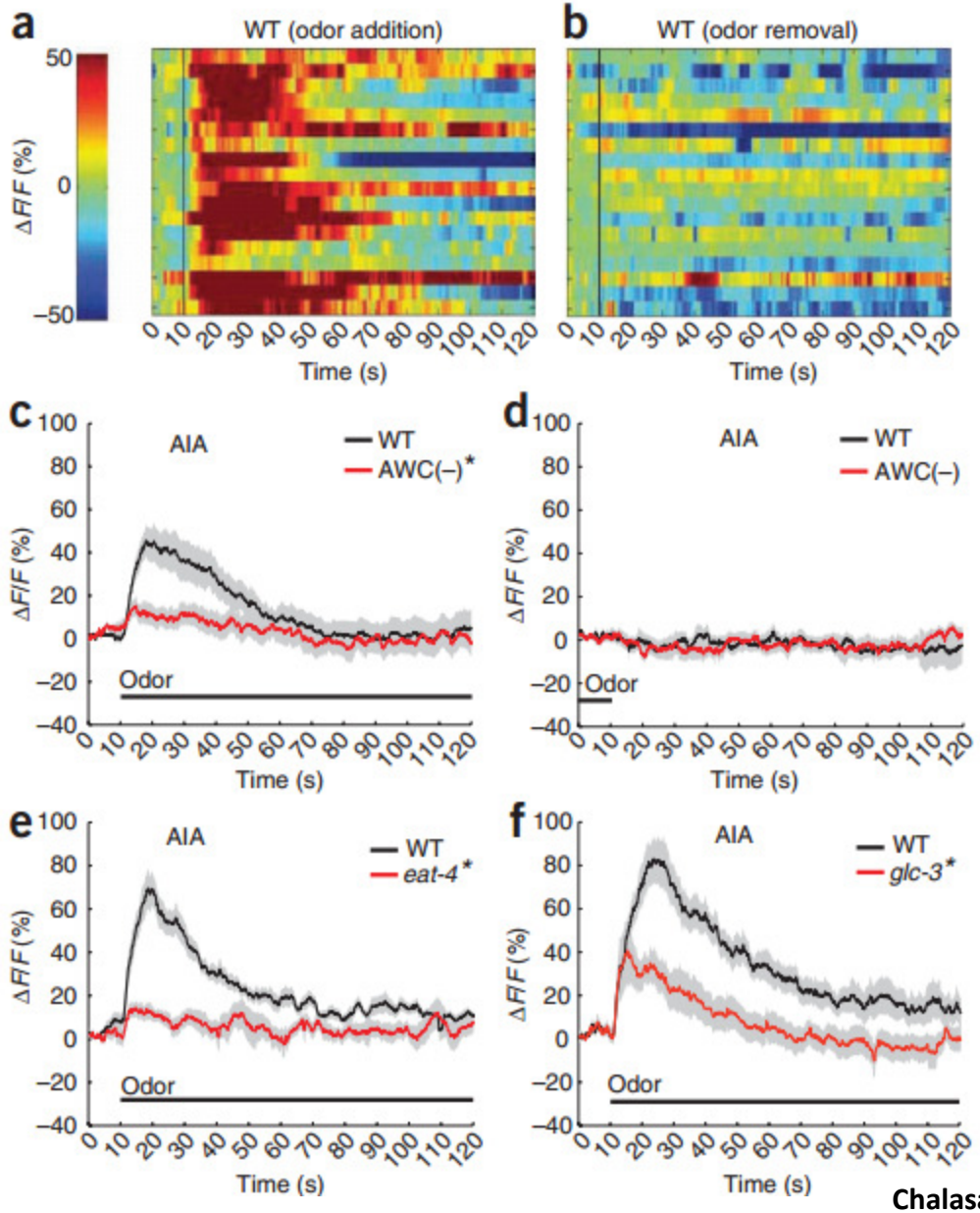


WormWeb.org/neuralnet

AWC inhibits AIA via *glc-3*

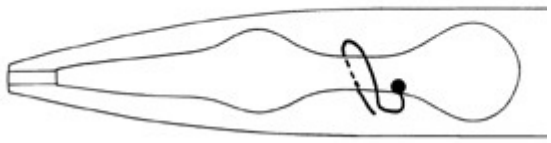


AIA

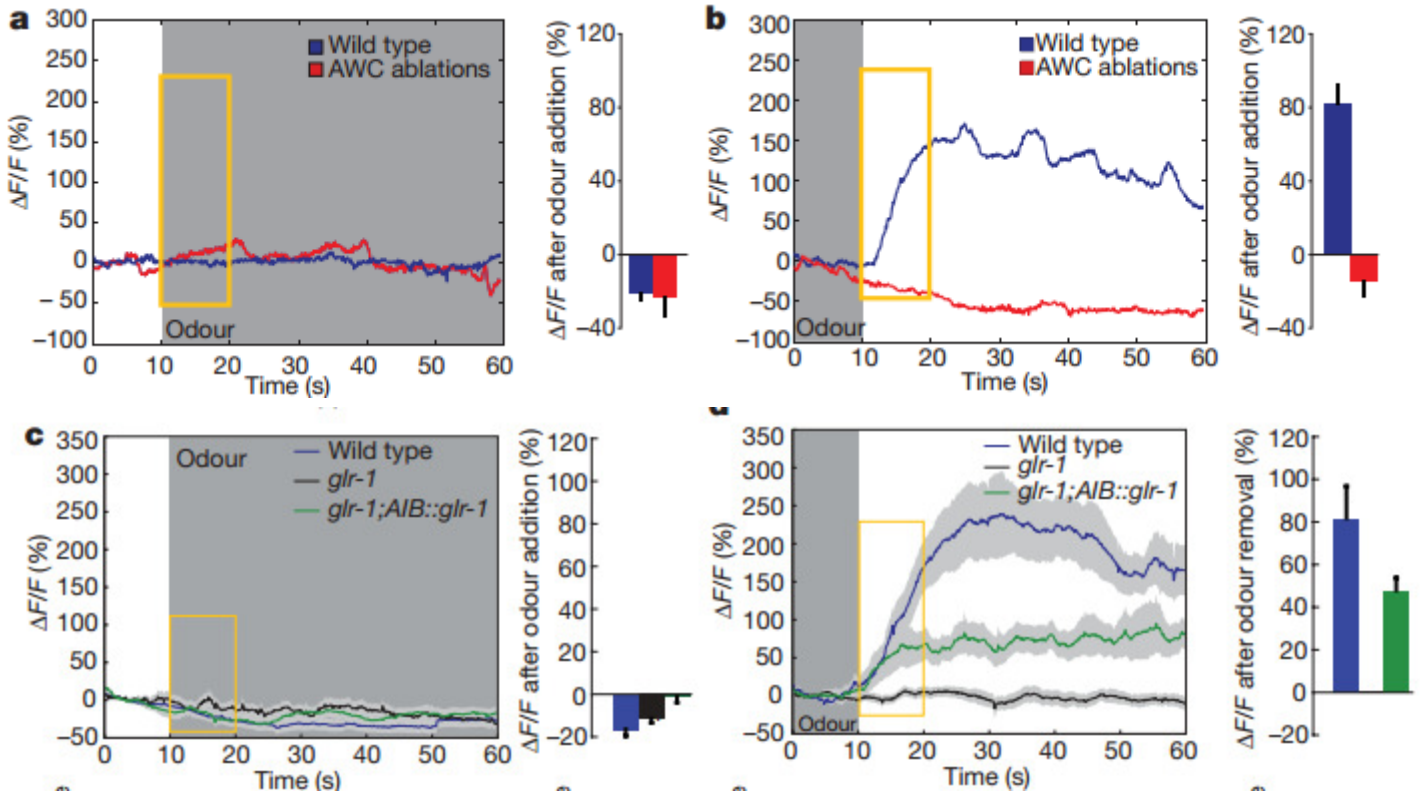


Chalasani..Bargmann 2010

AWC activates AIB via *glr-1*

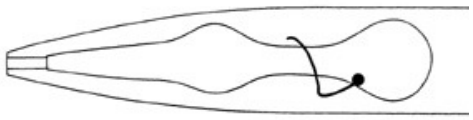


AIB

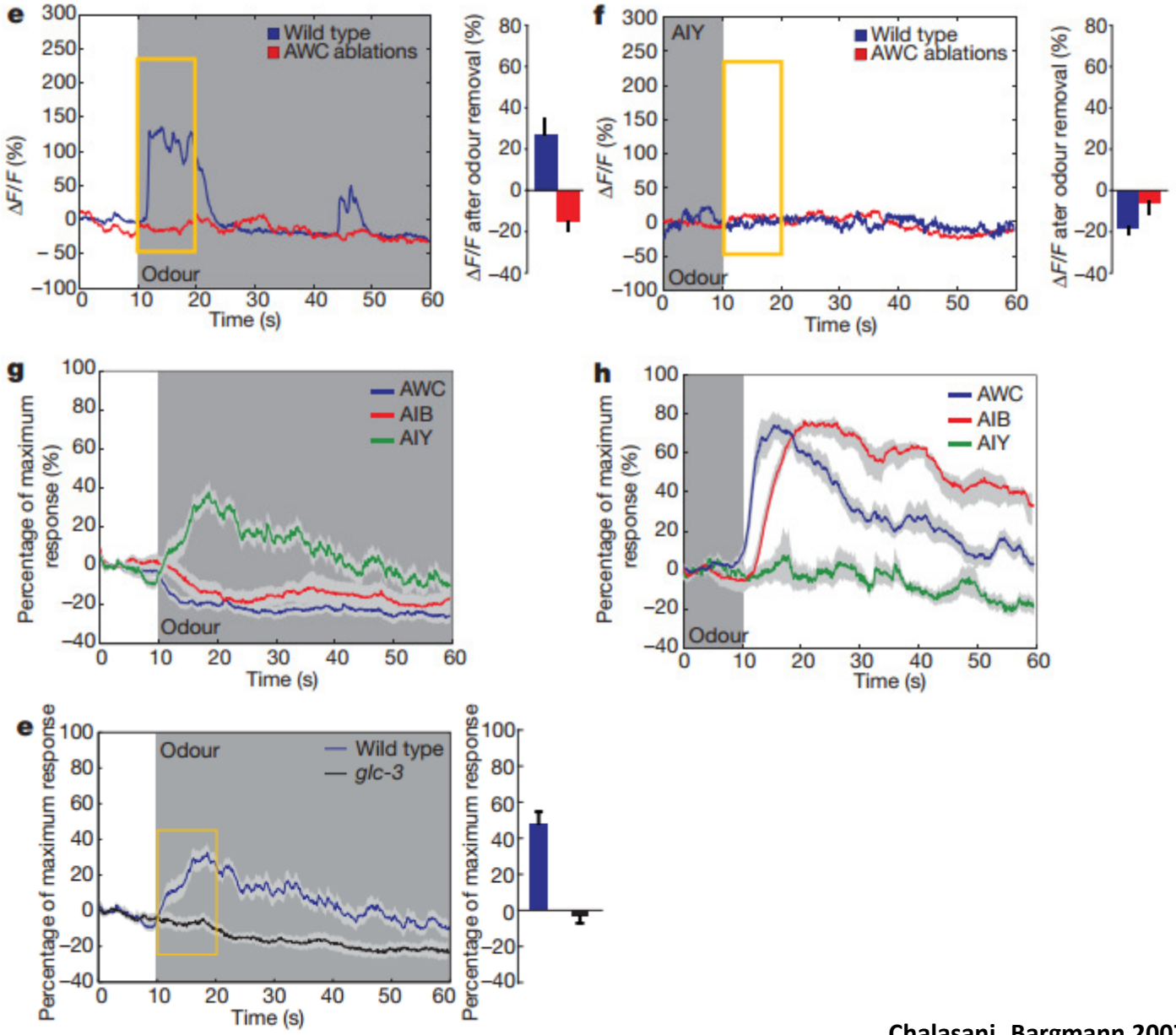


Chalasani..Bargmann 2007

AWC inhibits AIY via *glc-3*

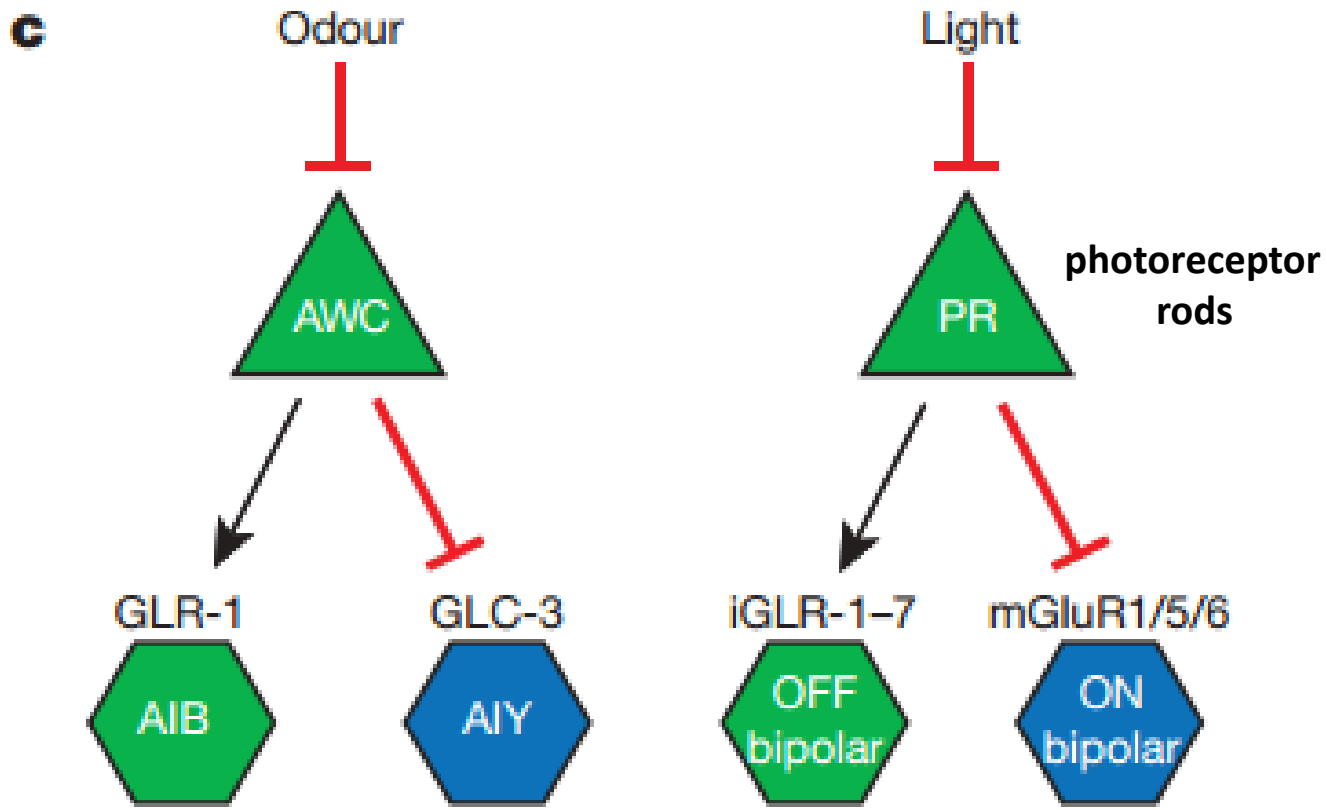


AIY



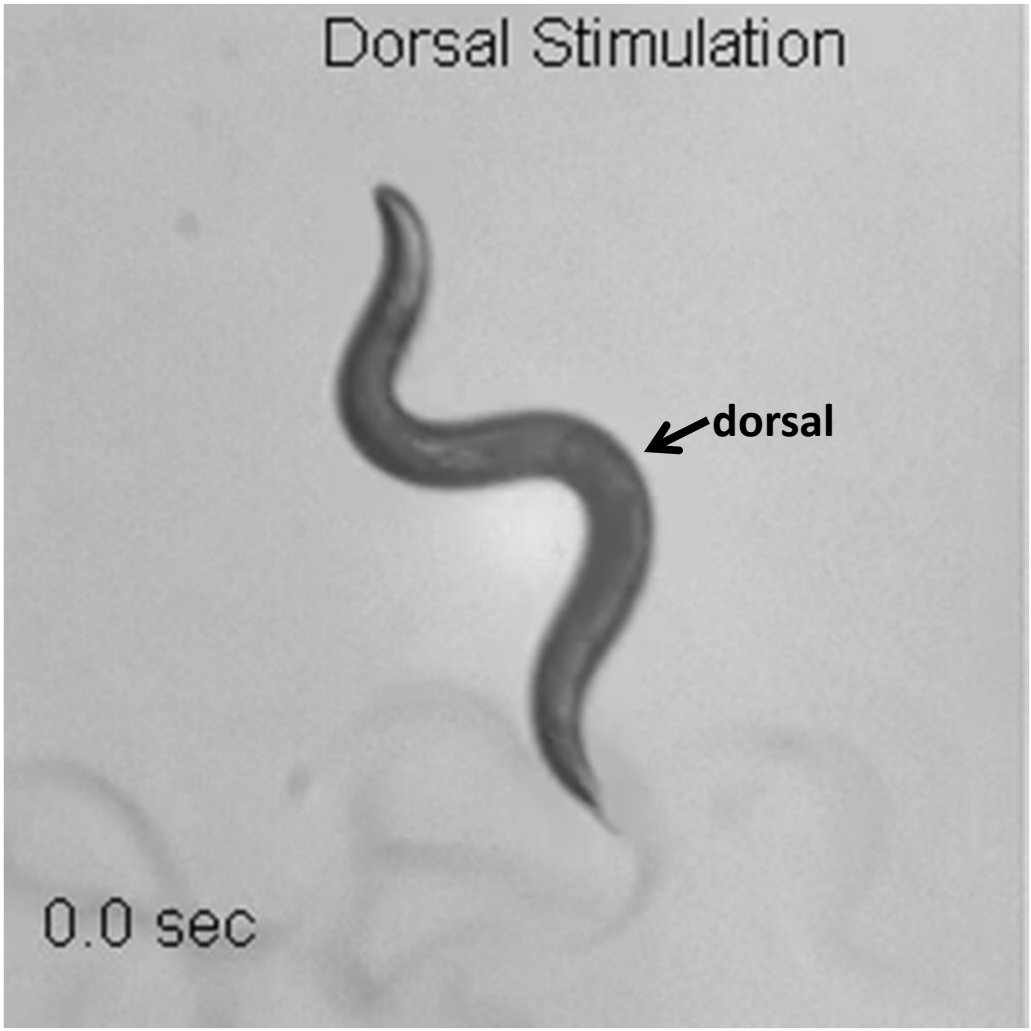
Chalasani..Bargmann 2007

Similar to sensory processing in the retina?



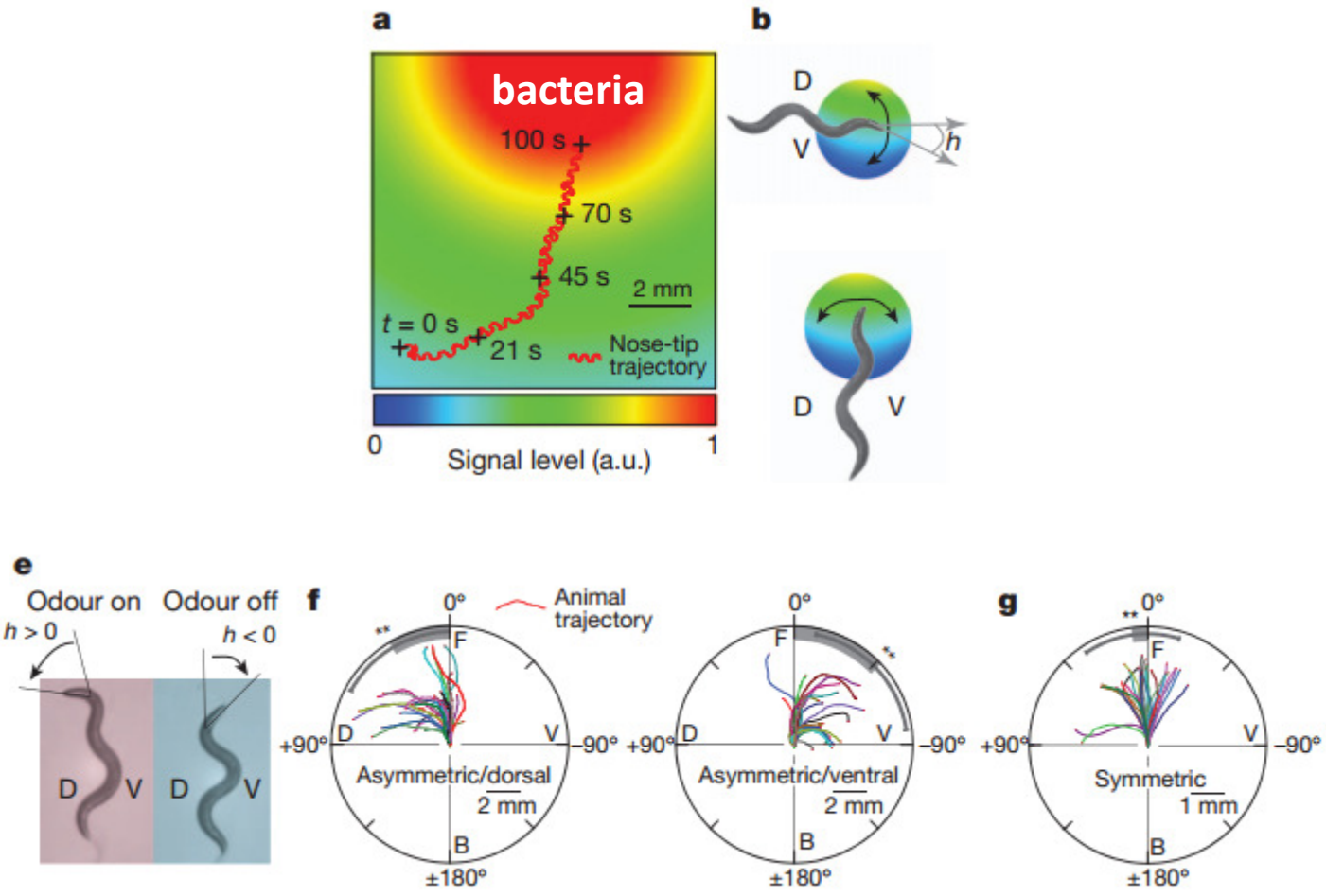
Chalasani..Bargmann 2007

Worm nose wiggles control turning in response to odors



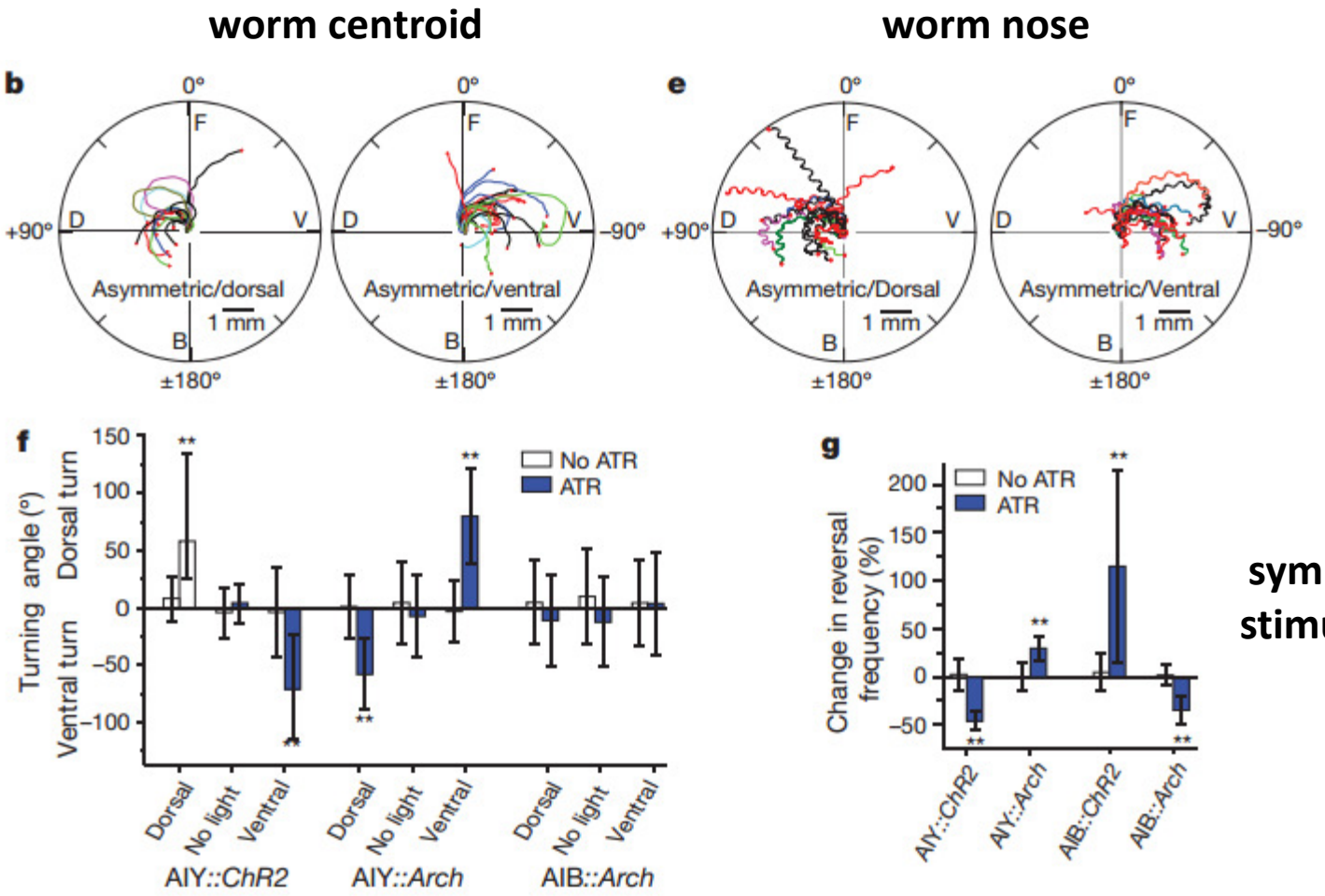
Kocabas..Ramanathan 2012

Worm turns in direction of odor



Kocabas..Ramanathan 2012

Activation of AIY during nose bending controls turning and reversals

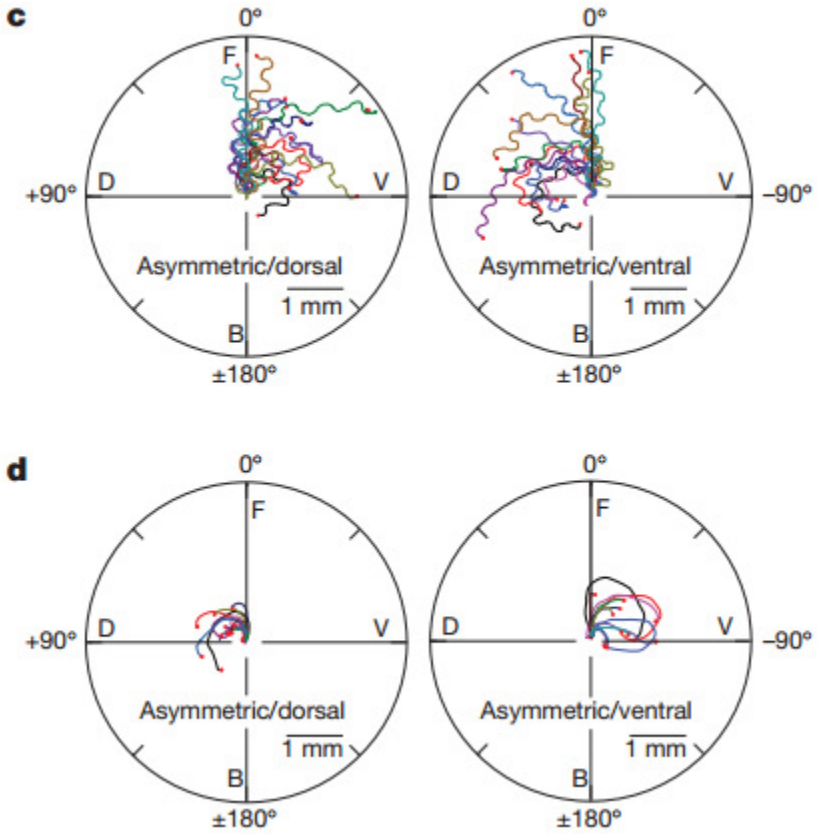


Kocabas..Ramanathan 2012

SMB activation causes turning in the nose direction, while RME activation causes turning in the opposite direction

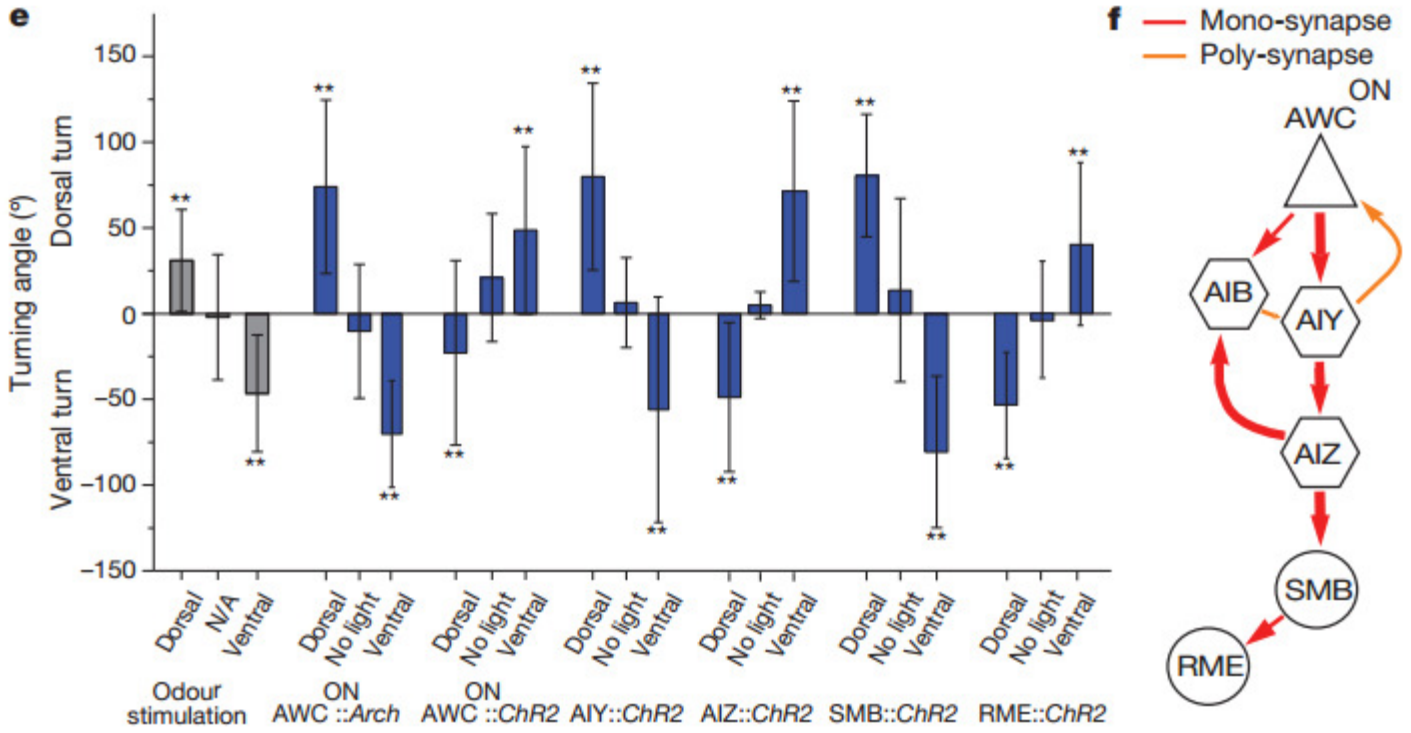
AIZ:

SMB:



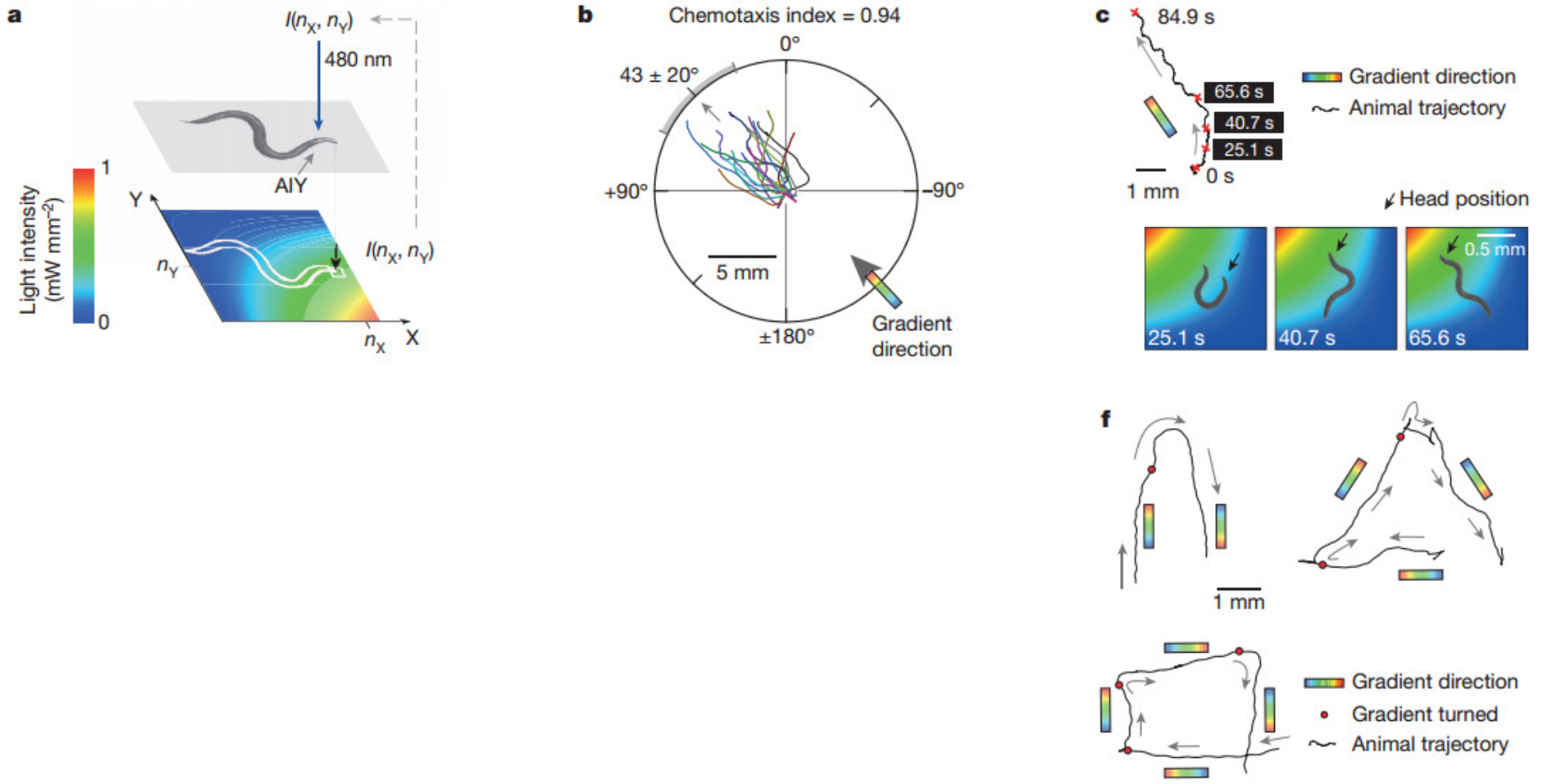
Kocabas..Ramanathan 2012

Activation of AIY & SMB and inhibition of AWC & AIZ & RME controls turning



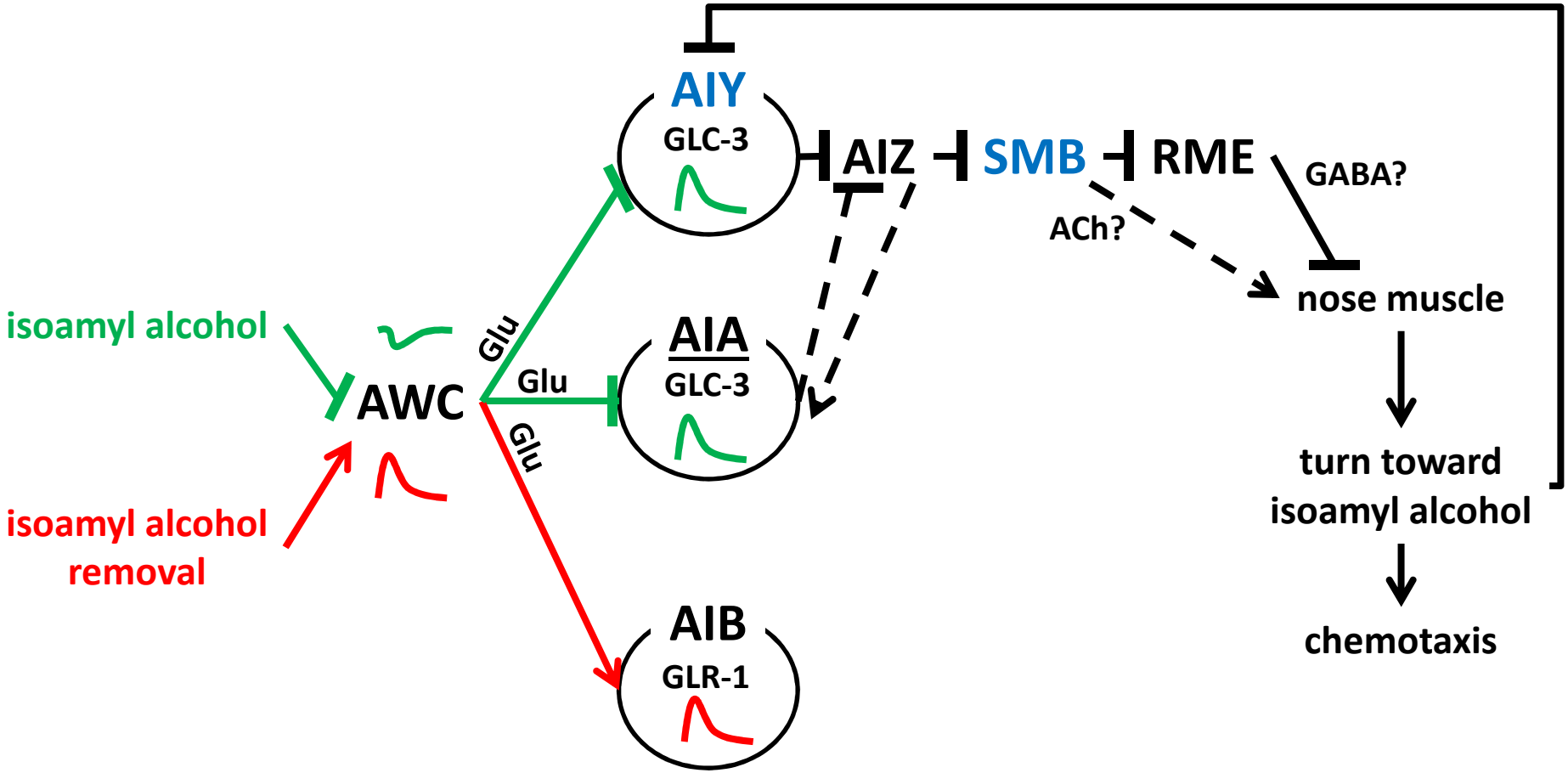
Kocabas..Ramanathan 2012

Light intensity-varying stimulation of AIY results in virtual chemotaxis



Kocabas..Ramanathan 2012

Odorant chemotaxis circuit



Derived from Bargmann..Horvitz 1993, Chalasani..Bargmann 2007, Kocabas..Ramanathan 2012