Isothermal Behavior in Caenorhabditis Elegans - The Neural Origin of Sensorimotor Integration

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ABSTRACT

- Caenorhabditis elegans have the ability to exhibit isothermal behavior up to a remarkable precision of a 0.05 degree difference. However, the neural circuitry underlying isothermal behavior remains elusive as it is very difficult to track neuronal activity in freely moving specimen.
- Furthermore, the computational power of their nervous system is often overlooked due to the small number of neurons - hundreds compared to a mammal's billions. Isothermal tracking appears to be a deterministic behavior that may be a product of a more complex processing system - a behavior facilitated by a network.
- There is strong evidence sensorimotor integration is occurring; the C. elegans are tracking temperature differences and coordinating their movements to the local temperature in a highly deliberate and precise manner. In this experiment, we created an assay plate over a thermal gradient and tracked the worm's movements
- We have proposed a model that underlies the circuitry behind isothermal behavior involving several neurons, including a well-established thermosensory neuron - AFD

INTRODUCTION

- C. elegans are often ignored when studying dynamic neural networks because it is a widely accepted notion in the scientific community that we need to study mammals like mice to understand the brain
- C. elegans only have 302 neurons - less than the millions that mice have and much less than the billions humans have, yet we still do not fully understand how all 302 neurons work together in a dynamic network, especially during isothermal behavior
- They make straight and deterministic paths along temperatures they associate with food, usually at cultivation temperature. They can sense temperature differences as small as 0.01 degrees Celsius
- They somehow correlate the temperature of their environment and movements of their heads in a highly precise manner - there is some sort of sensorimotor integration occurring

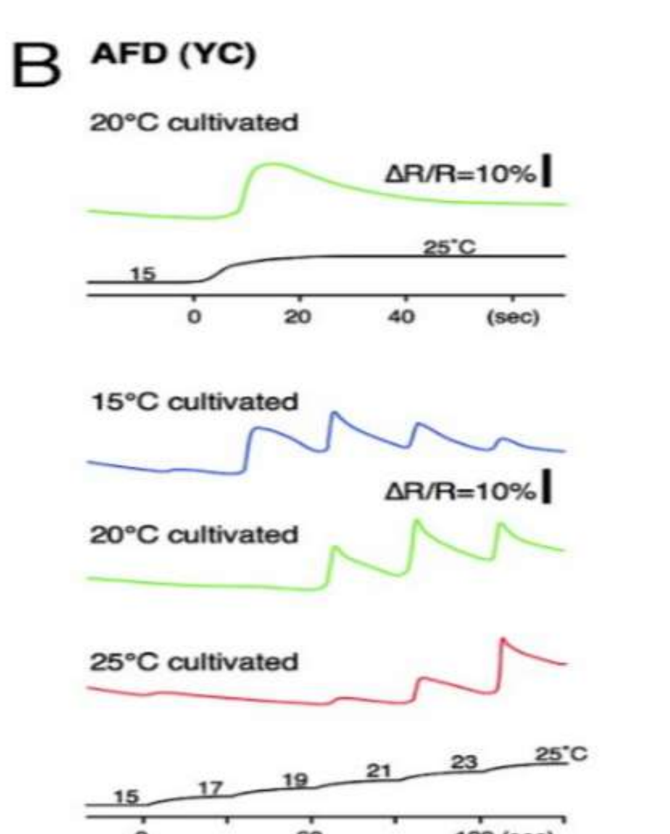


Figure 1. AFD is the main thermosensory neuron in C. elegans and it depolarizes upon temperature increase. The threshold at which it starts depolarizing can change depending on cultivation temperature. Kimata 2012

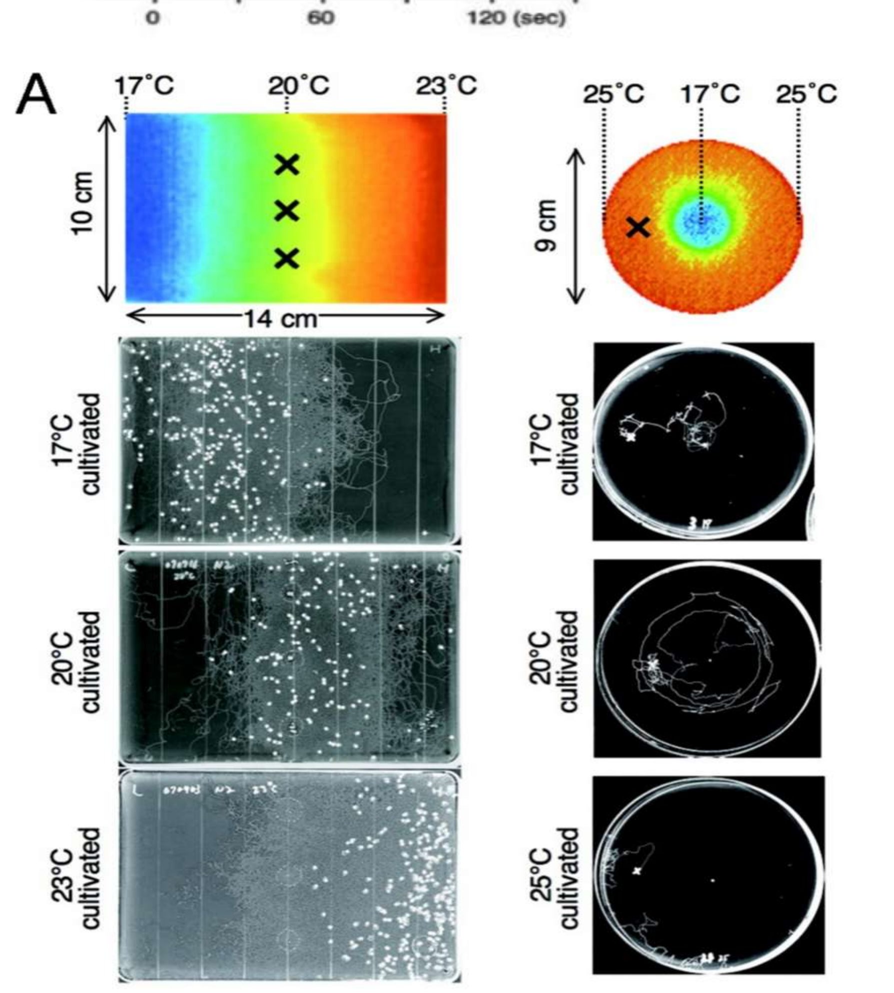


Figure 2. The worms will gravitate towards the temperature in which they were cultivated because they associate that temperature with food . Kimata 2012

OBJECTIVES

- C. elegans move their heads back and forth between temperatures on a thermal gradient, in an oscillatory pattern, in a consistent and deterministic manner
- In order for them to stay on an isothermal pathway, there must be a way for them to compare the old and the new temperature. AFD has been extensively studied but there must be multiple neurons involved because their head movements are so synchronized with the temperature sensing
- Neurons involved in isothermal behavior are often studied in isolation – usually through laser ablation experiments
- The goal of this project is to discuss the neural complexity of a well-established, but simple behavior

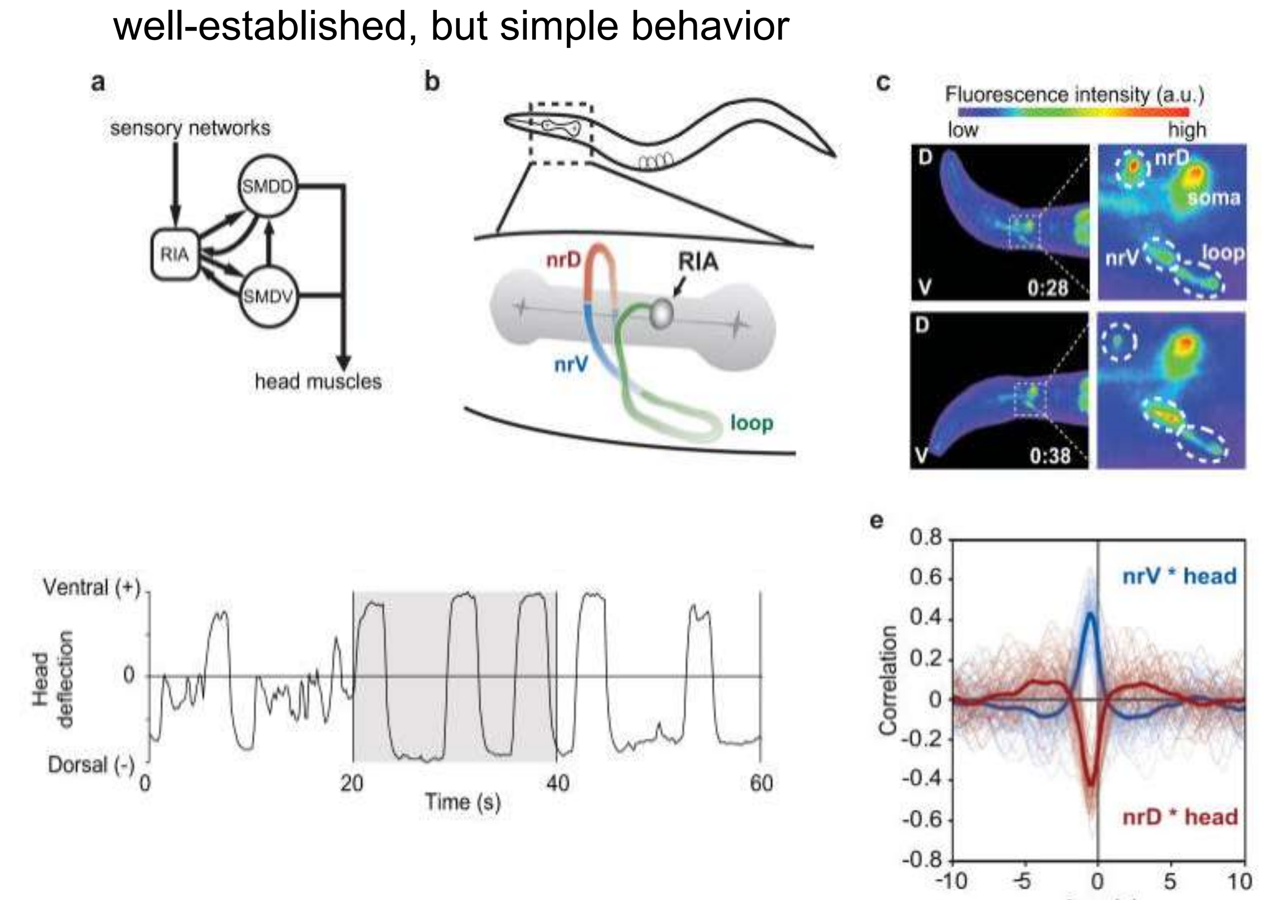


Figure 3. RIA is an interneuron that mediates the sensory networks and motor neurons, SMD. Hendricks 2012

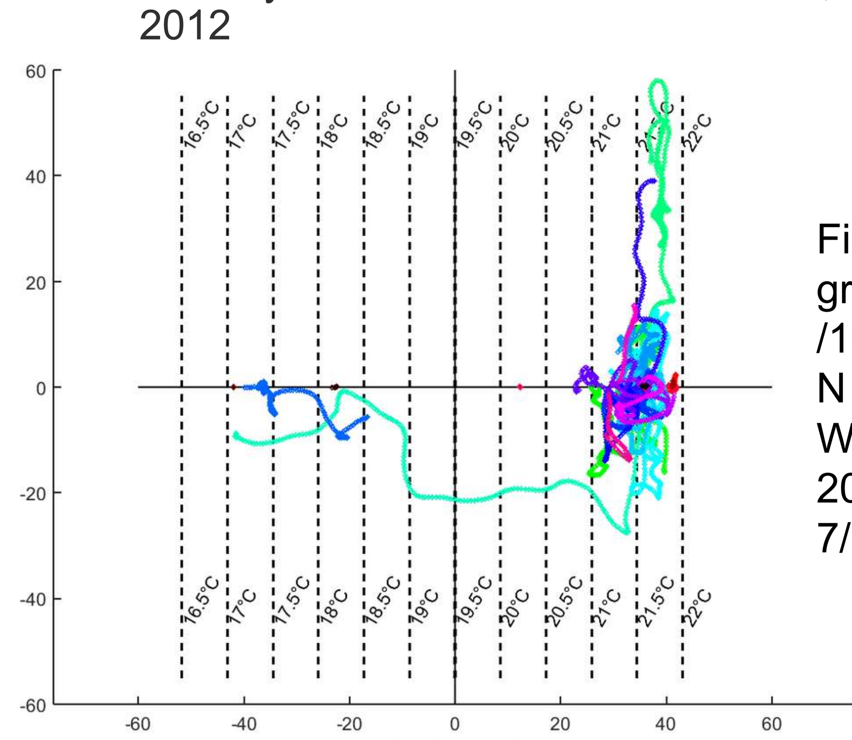


Figure 4. Temperature gradient: 16.6°C-22.4°C /10 cm (0.58°C/cm)
N = 10-15 worms
Worms were cultured at 20 °C. Data was taken 7/1/16

MATERIALS & METHODS

- N2 worms cultivated on OP50 E. coli at 20 degrees Celsius
- Aluminum plate powered by peltiers and a liquid cooling system to produce a stable thermal gradient, temperature fluctuations are less than 0.01 degrees Celsius
- Assay plate was made with 0.5 mm sheet of 2% agar, placed directly on the temperature plate to maximize thermal conductance

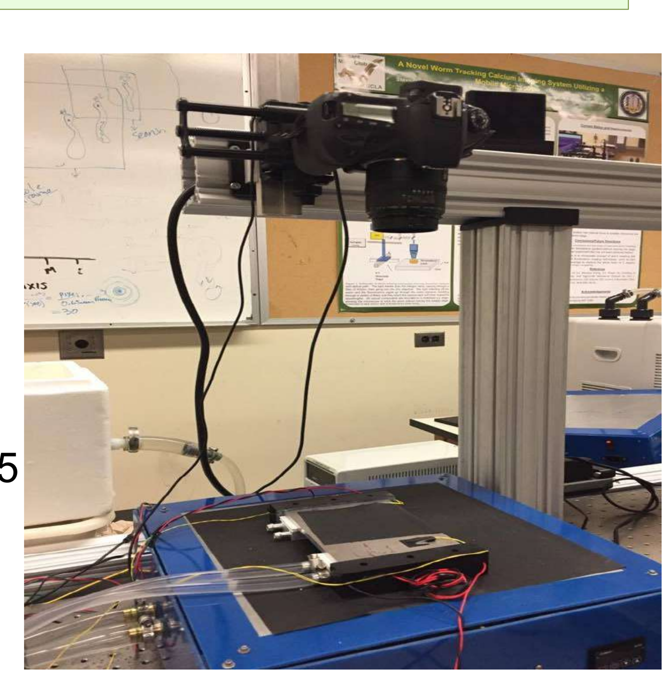


Figure 5. Worm movements are captured by a Canon 60D camera mounted over a custom temperature plate shown in figure 6

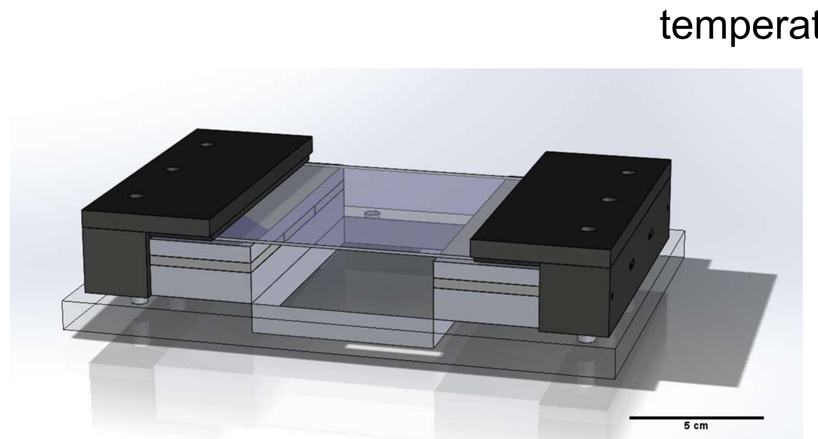
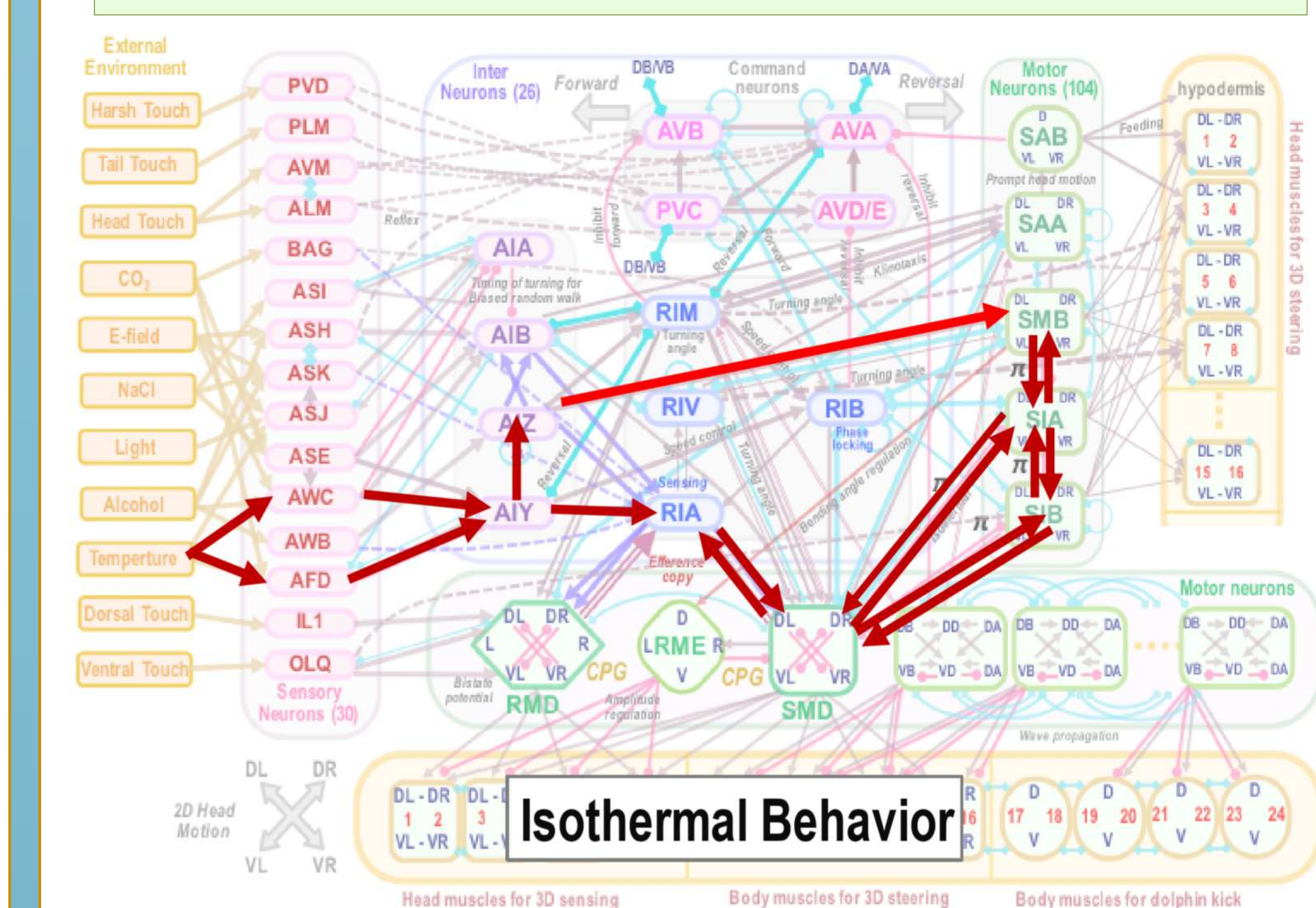
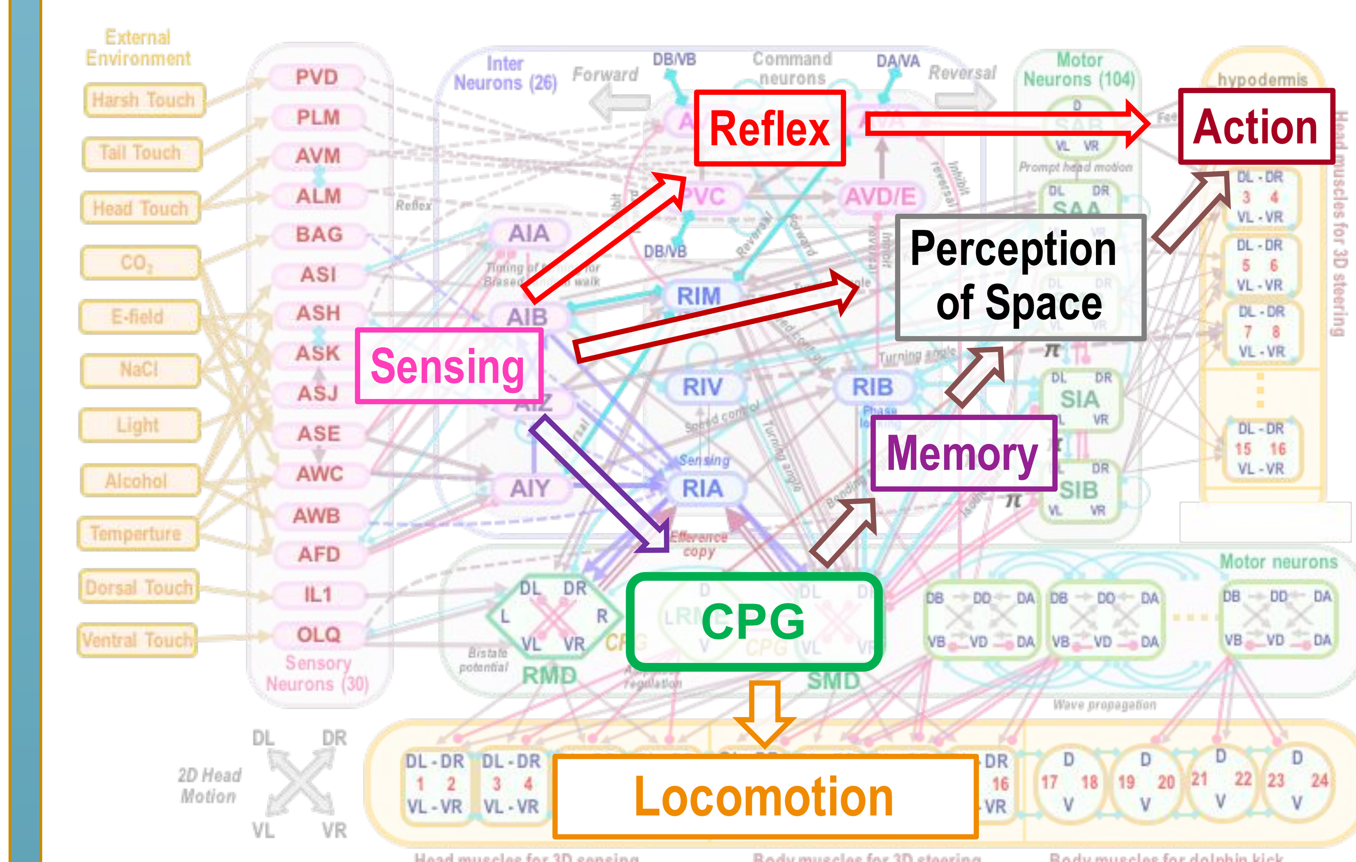


Figure 6. An aluminum plate is fixed above 6 peltiers powered by an electric current. 3 creating a hot side and 3 creating a cold side, effectively creating a thermal gradient.

MODELS



Neural network required for isothermal behavior - Arisaka 2016



Dynamic connectome of C. Elegans for perception of 3D space and navigation - Arisaka 2016

FUTURE DIRECTIONS

- Using a line confocal microscope with a motorized stage, we will be able to track the worm's movements over a thermal gradient and also observe neural activity
- This will eliminate the need for immobilization or laser ablation and allow us to observe neural networks in real time as a worm moves in its natural form

REFERENCES

Hendricks, M., Ha, H., Maffey, N., & Zhang, Y. (2012). Compartmentalized calcium dynamics in a C. elegans interneuron encode head movement. Nature, 487(7405), 99–103. http://doi.org/10.1038/nature11081

Kimata, T., Sasakura, H., Ohnishi, N., Nishio, N., & Mori, I. (2012). Thermotaxis of C. elegans as a model for temperature perception, neural information processing and neural plasticity. *Worm*, *1*(1), 31–41. http://doi.org/10.4161/worm.19504

Tsukada, Y., Yamao, M., Naoki, H., Shimowada, T., Ohnishi, N., Kuhara, A., Shiin, I., & Mori, I. (2016). Reconstruction of Spatial Thermal Gradient Encoded in Thermosensory Neuron AFD in Caenorhabditis elegans. Journal of Neuroscience, 36(9), 2571-2581. doi:10.1523/jneurosci.2837-15.2016

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