Measuring C. elegans Touch Sensitivity

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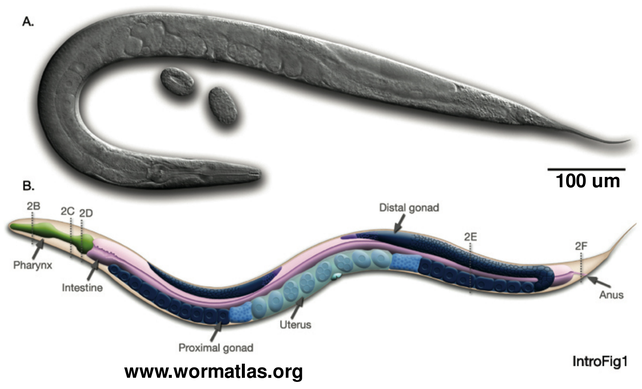
Introduction

Touch sensation is one of our least understood senses, yet is vital for many biological processes such as locomotion and embryonic development. More generally, the conversion of mechanical forces into electrochemical signals is necessary for many functions affected by disease, such as hearing and blood pressure regulation.

Caenorhabditis elegans is widely used to study the molecular basis of mechanotransduction. We propose the use of microelectromechanical force sensors to more accurately apply forces for the study of touch in microorganisms and cells. In contrast with the typical eyebrow hair assay, a MEMS force sensor provides significantly better force resolution, time resolution and repeatability.

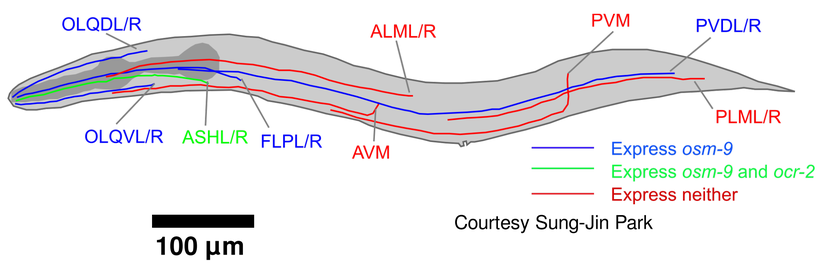
We have previously reported on the development of a stationary SU-8 two-axis force sensor for the study of C. elegans [1]. In this work, we use a manually positioned electrostatic force probe to study the behavioral response of several C. elegans strains to force.



Experiments

We investigated the touch sensitivity of four C. elegans strains; two strains with normal mechanosensitivity (wild-type and HA1134) and two strains with reduced touch sensitivity (osm-9 and ocr-2 null). Both ocr-2 and osm-9 encode TRP ion channel subunits and are activated by noxious stimuli (e.g. touch, osmolarity changes).

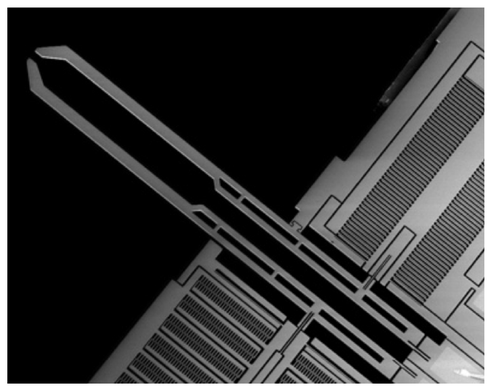
By placing the force sensor in the path of a worm, the threshold force for a behavioral response could be measured.

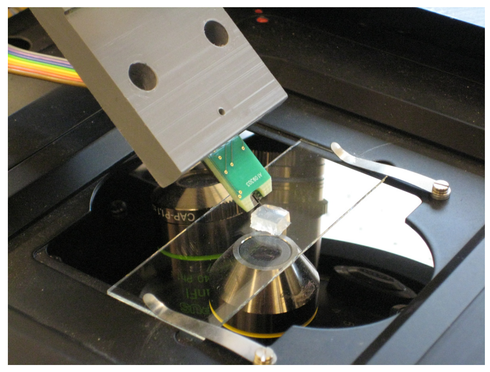


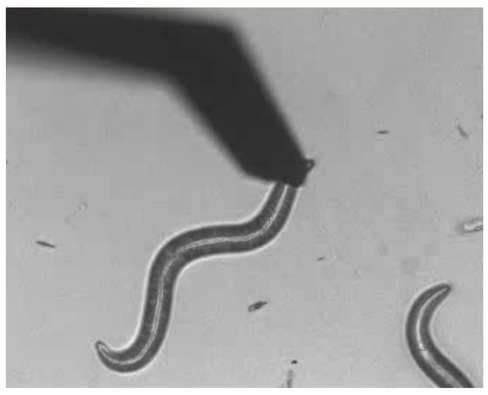
Device and Experimental Setup

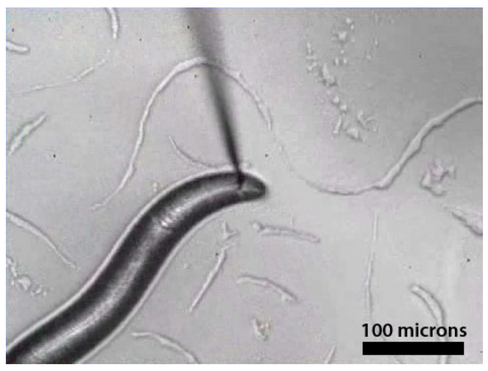
We used the capacitive foce sensor from a commercial MEMS based microgripper with force feedback (FT-G100, FemtoTools GmBH). The force sensor fabrication and characterization details have been previously reported [2]. The actuator arm was manually removed prior to experiments. The force sensor was calibrated by measuring the deflection for a known load. The force resolution in the measurement bandwidth (350 Hz) was approximately 10 nN.

A fine tungsten wire (radius < 100 nm) was mounted to the tip of the silicon arm in order to avoid occluding the field of view and more easily identify the contact location.







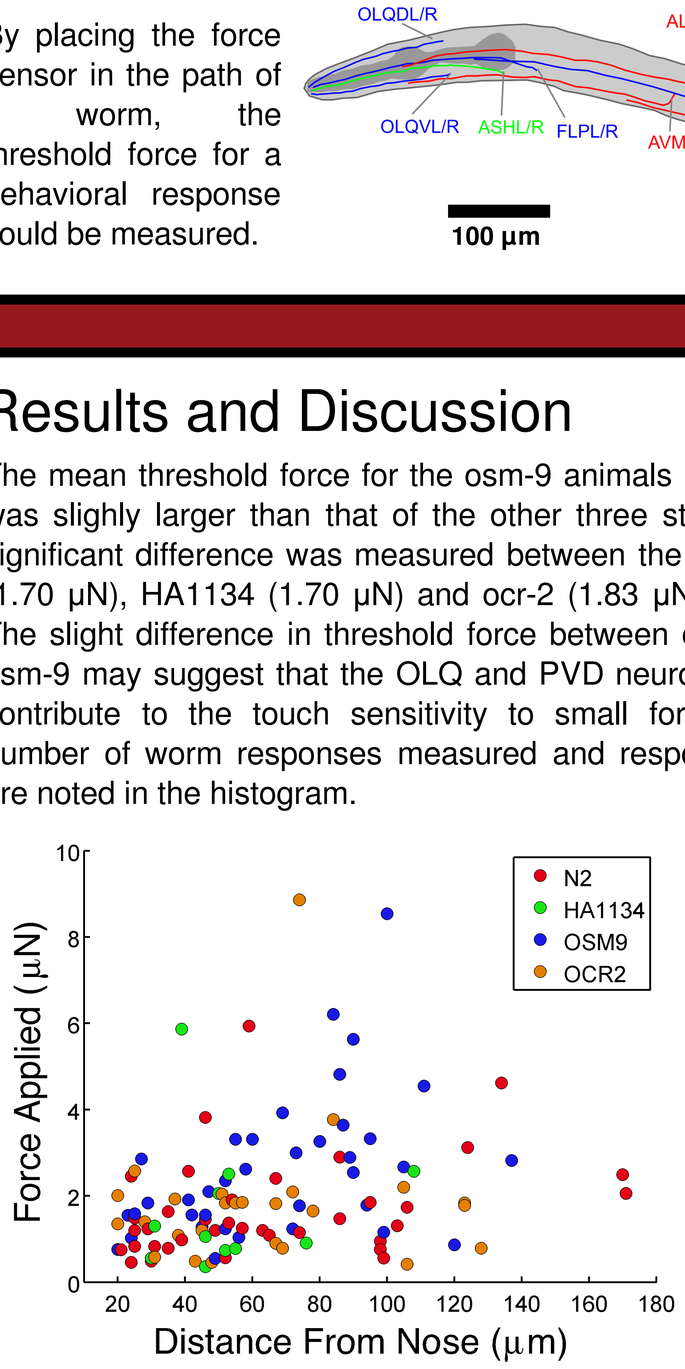


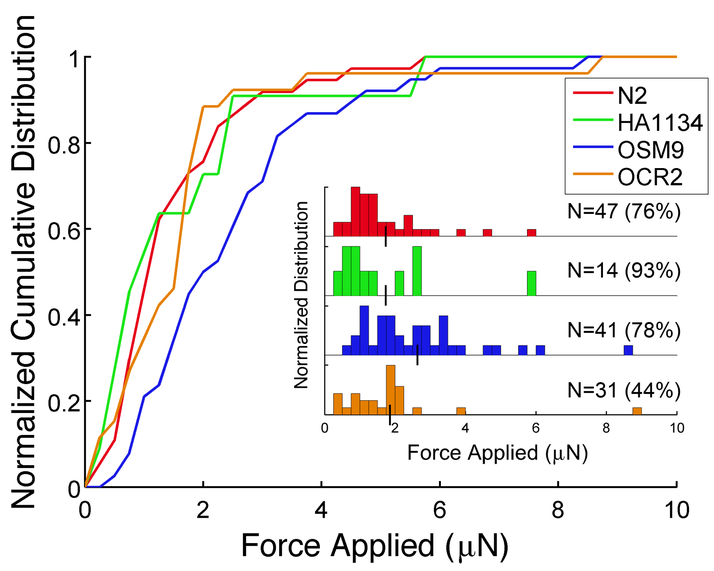
Worms were synchronized and grown at room temperature to obtain L4 animals, which were placed on an agar pad that had not been seeded with bacteria. The agar pad was placed on the motorized stage of an inverted microscope, enabling manual control of the pad with respect to the force probe, mounted above, which was controlled with a separate positioning motor.

Synchronized video and data were recorded. Every contact between the worm and probe was manually scored (response, no response) and the timestamp was recorded. These timestamps were used to automatically find the force values.

Results and Discussion

The mean threshold force for the osm-9 animals (2.61 µN) was slighly larger than that of the other three strains. No significant difference was measured between the wild-type (1.70 µN), HA1134 (1.70 µN) and ocr-2 (1.83 µN) strains. The slight difference in threshold force between ocr-2 and osm-9 may suggest that the OLQ and PVD neurons partly contribute to the touch sensitivity to small forces. The number of worm responses measured and response rate are noted in the histogram.





The threshold force increases slightly with distance from the nose. This may be due to the higher innervation density of the nose (ASH, IL1, OLQ, CEP, FLP) than the head posterior to the nose (ALM, PVD) with mechanosensory neurons. The loss of ocr-2 did not appear to affect the behavioral response, suggesting that other neurons besides ASH play a dominant role for forces applied > 20 µm from the nose.

Conclusions

We have demonstrated the application of a MEMS force sensor to the study of mechanotransduction in C. elegans. The behavioral responses for several touch insensitive mutants were measured.

Acknowledgements

This work was supported by National Science Foundation (NSF) CAREER Award ECS-0449400 and the NSF IREE program, as well as the National Institutes of Health (NIH) under grants EB006745 and NS047715. JCD was supported in part by a NDSEG fellowship.

References

[1] J.C. Doll et al, "SU-8 Foce Sensing Pillar Arrays for Biological Measurements", Lab on a Chip, In press (2009)
[2] F. Beyeler et al, "Monolithically Fabricated Micro-Gripper with Integrated Force Sensor for Manipulating Micro-Objects and Biological Cells Aligned in an Ultrasonic Field", JMEMS, Vol. 16, p. 7-15 (2007)