Search for Magnetotaxis in *Caenorhabditis elegans*

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Introduction and Theory

- C. elegans is commonly used as a model organism and is an attractive specimen for the study of neural networks.
- UCLA's Elegant Mind Club is testing the response of C. elegans to a variety of stimuli.
- Last year, researchers at the University of Texas at Austin claimed to have observed magnetotaxis in C. elegans.
- To test this claim, we constructed a cage of three sets of two parallel rings capable of completely controlling the magnetic field at its center.

Hypothesis

- We attempt to replicate the UT Austin experiment and observe C. elegans' response to magnetic fields.
- We expect that C. elegans will have a preferred direction of migration with respect to the magnetic field vector.

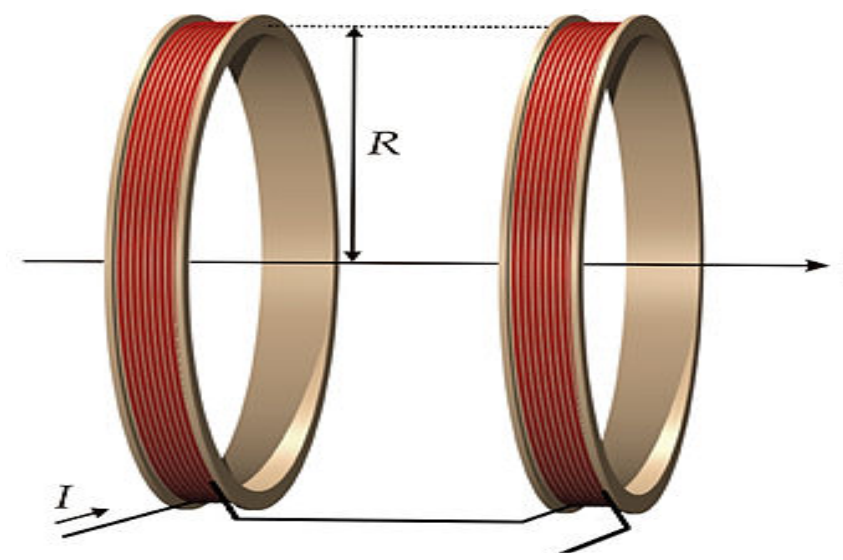

Figure 1: A Helmholtz pair with two rings of radius R. The z axis is defined as the axis of symmetry.

- From the Biot-Savart Law, $\vec{B} = \frac{\mu_0}{4z}\int_c \frac{I\vec{dl}\times\vec{r}}{|\vec{r}|^3}$, the on-axis field of a circular ring of current is:

$B_z = \frac{\mu_0 R^2 I}{2(z^2+R^2)^{\frac{3}{2}}}$ and $B_x = B_y = 0$ by symmetry.

- For two coils of radius R and separation L, each with N coils, and I current, the on-axis field is:

$$\mathrm{dB}(z) = \frac{\mu_0 R^2 NI}{2}\left(\left[R^2 + \left(\frac{L}{2}+z\right)^2\right]^{-\frac{3}{2}} + \left[R^2 + \left(\frac{L}{2}-z\right)^2\right]^{-\frac{3}{2}}\right)$$

- At the origin, z=0, so $\vec{B} = \frac{\mu_0 R^2 NI}{(R^2+L^2/4)^{\frac{3}{2}}}\hat{z}$.
- When L=R, a region of constant magnetic field is produced in the center of the pair.
- Our Helmholtz cage is not perfectly symmetrical. Plugging in our measurements of the apparatus gives: $B_x = 2.53 \cdot I$; $B_y = 2.21 \cdot I$; $B_z = 2.85 \cdot I$.

Method and Apparatus

- The Earth's magnetic field at our coordinates has components: 0.24 Gauss north, 0.05 Gauss east, 0.40 Gauss vertical (from National Geophysical Data Center data).
- A gauss meter was used to check the magnitude of the field.
- Using a Labview program, we set the coils to first cancel the Earth's field and then, after a particular amount of time, to set up a uniform field.

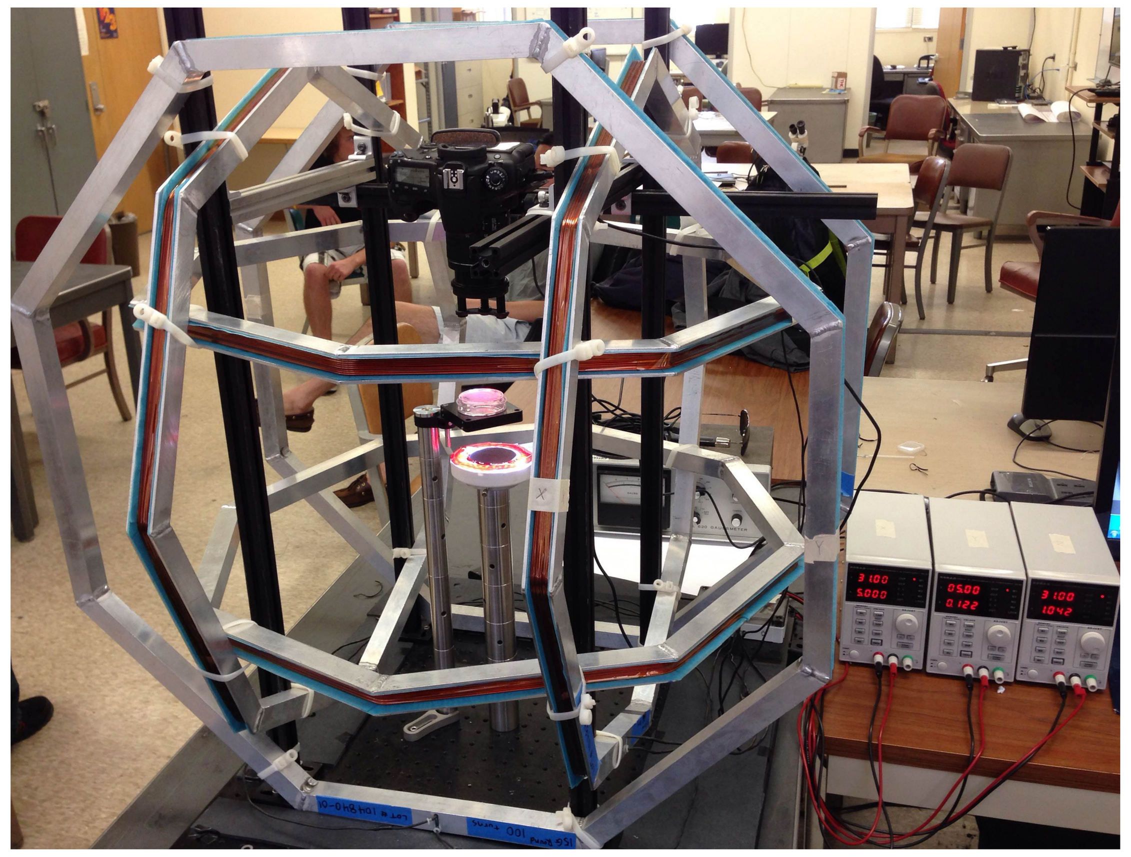

Figure 2: Our Helmholtz cage. The hexagonal shape of the rings produces no significant corrections to our calculations.

- We used C. elegans samples raised until young adulthood, then washed and placed them on agar without food.
- The samples were placed at the center of a petri dish and allowed to disperse.
- We applied fields up to 10 Gauss in ten minute intervals with a 6.5 cm x 4.3 cm field of view.
- These experiments were repeated under a wide variety of conditions, preparation procedures, and Helmholtz coil parameters.

Analysis

- In all cases, we observed an apparently random dispersion of worms, with no preferred direction.
- There were no apparent differences in worm migration with or without a field, or when the Earth's field was canceled.
- We traced the paths of the worms across the plates by overlaying a sequence of images.
- The following figures display worm motion over a period of 32 seconds.

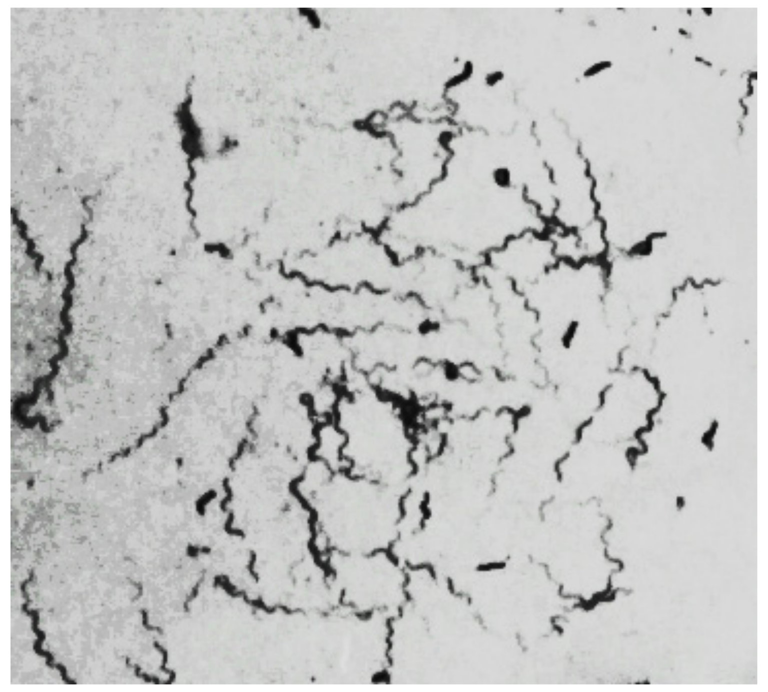

Figure 3: Worm paths under Earth's magnetic field.

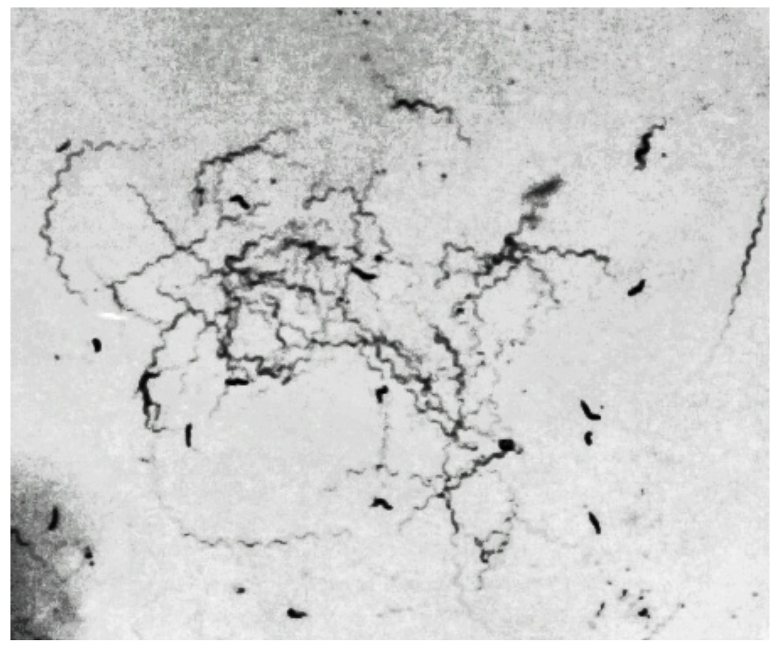

Figure 4: Worm paths under a constant horizontal 10 Gauss field and zero vertical field. The field vector in the image points to the left.

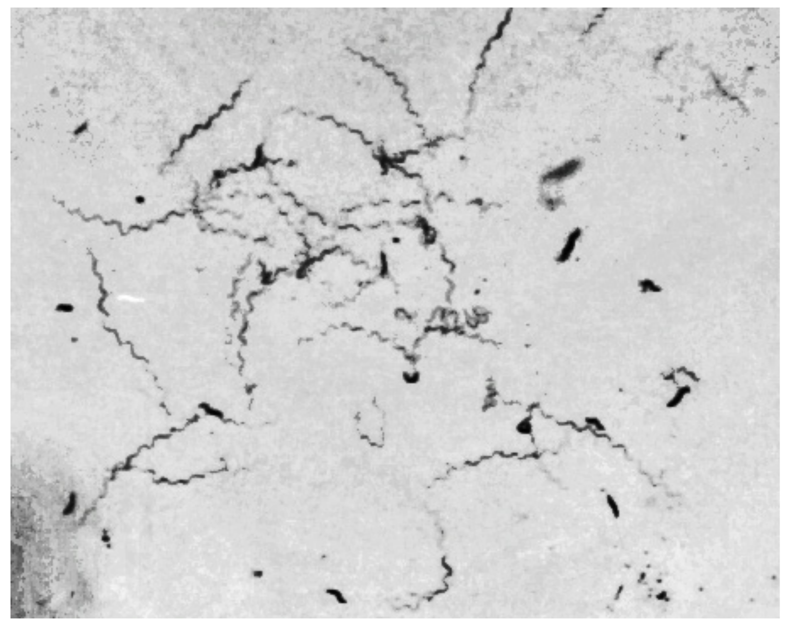

Figure 5: Worm paths under a constant vertical 10 Gauss field and zero horizontal field. The field vector points down into the image.

- Following the UT Austin group, we defined a "Magnetotaxis Index" as the number of worms which are traveling in the direction of the magnetic field vector minus the number which are traveling against it, divided by the total number of worms:
- We also defined our own "Position MI" as the $MI = \frac{L-R}{L+R}$. difference in the number traveling in a particular direction at some instant.

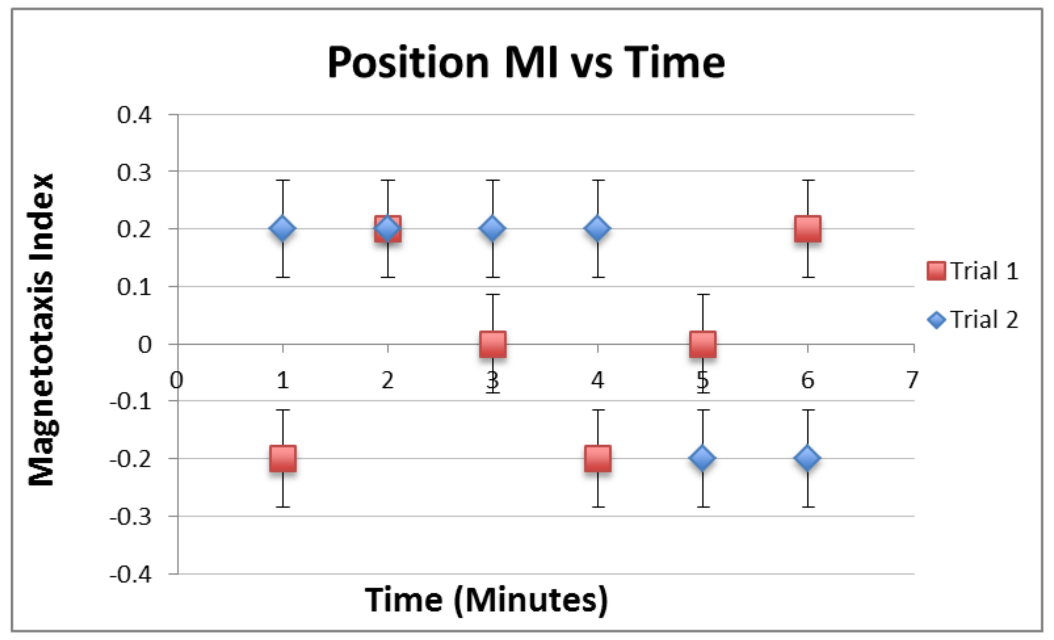

Figure 6: Position MI. If magnetotaxis had taken place, we would expect the index to increase over time. Instead, it oscillates around zero.

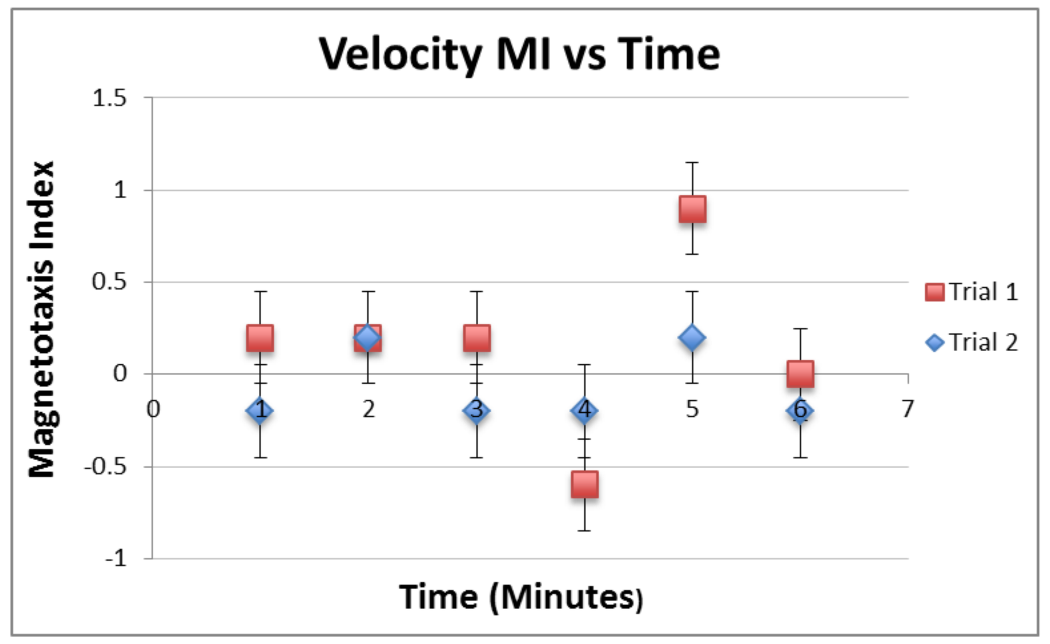

Figure 7: Velocity MI. If magnetotaxis was occurring, we would expect the index to consistently be greater than zero. Instead, we observed a random distribution of positive and negative value.

Conclusion

No magnetotaxis was observed. After searching for a response in dozens of tests under a wide variety of conditions, we must conclude that there is no response.

We strongly refute the claim made by the UT Austin group of magnetotaxis in C. elegans.

References

- National Geophysical Data Center

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