Effects of Near-Zero Magnetic Field Exposure on *Xenopus laevis*

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Abstract

The effects of space travel on living organisms are not well understood. This is an important question to study as space consists of microgravity, high radiation, and zero geomagnetic field – a very different environment from Earth. Although the effects of microgravity and space radiation are more understood, there are fewer studies on near zero magnetic fields (MFs). MFs are produced by moving electric charges. Previous space studies suggested that near zero MF may alter embryo growth. To better understand how space MF alters tissue growth, we sought to identify and assess the effects of near zero MF on animal health using the clawed frog, *Xenopus laevis* – a model organism with well-documented development and high regenerative ability. We hypothesize exposing *Xenopus* to near zero MFs will result in decreased regeneration, and defects in development and wound healing.

First, we focused on constructing an apparatus, the Magshield box, to simulate space MF. The Magshield box has an exterior made of Mu metal, which blocks MFs and therefore creates a near zero MF in the interior of the box. One chamber in the box generates the Earth's normal MF (~45µT) using Helmholtz coils and serves as the control condition; the second chamber maintains near zero MF and is the experimental (space-like) condition. We have successfully built the Magshield box and confirmed that the two chambers generated the target MFs. To test the effects of MF alteration, we will place *Xenopus* embryos of the same age in each chamber and examine whether near zero MF alters development and tissue regeneration. Studying how the quantum effects of magnetism affect living systems may lead to the development of new strategies for safer space travel and also increase the knowledge in quantum biology.

Biological Effects of Magnetic Fields

- Magnetic fields are produced by moving charges or magnetic materials and are known to interact with subatomic particles.
- Space magnetic fields are near zero µT
- Magnetic fields have been shown to alter many elemental and chemical properties including nuclear and electronic spin states, splitting of spectral lines, energy levels, orientation of magnetic moments, reaction rates, and concentrations.
- Biochemical pathways define and drive many physiological outcomes. Magnetic fields are known to affect chemical species important in biological processes, such as reactive oxygen species; magnetic fields likely produce subtle biological phenotypes.
- We intend to study the effects near zero magnetic fields because these are experienced in space. As we humans, biological creatures, continue to pursue space travel, it is important to understand the effects the space environment will have on our natural physical processes, including tissue growth

Animal Model: *Xenopus laevis*

Figure 1

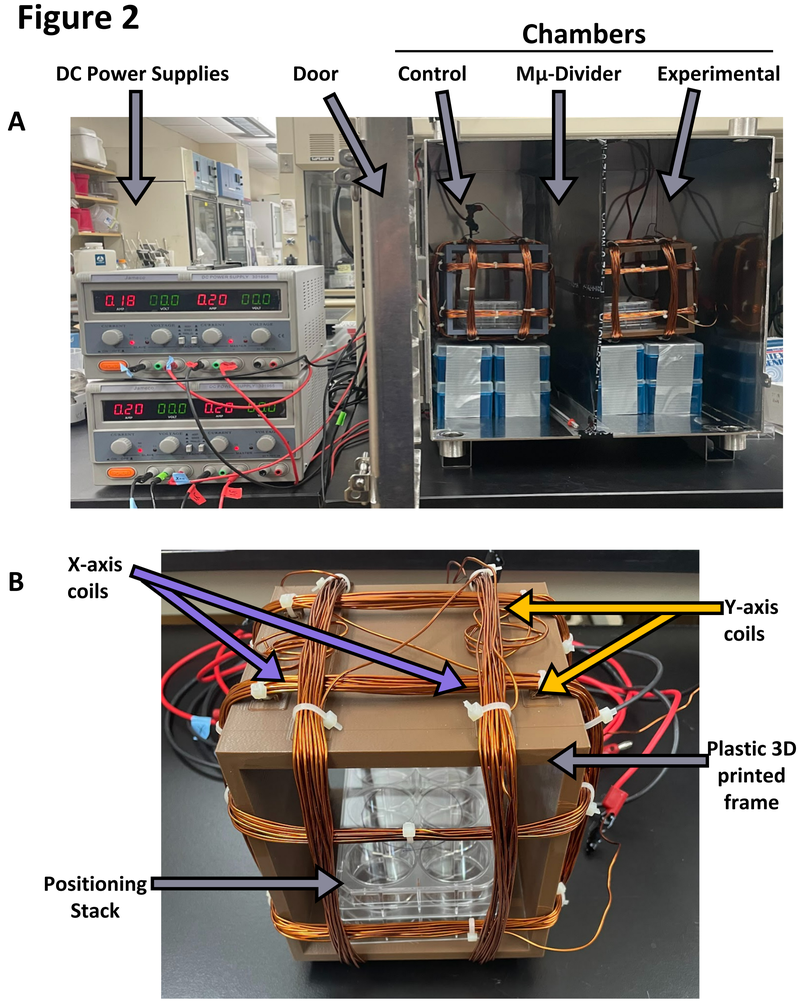
Figure 1. (A) *Xenopus laevis* stage (st.) 2 embryo (B) st. 40 tadpole (C) Adult *Xenopus laevis* female. (not to scale)

Hypothesis

- Previous studies show defects in development and decreased cell proliferation
- *Xenopus* embryos will have abnormal defects
- Tail regeneration and wound healing will be inhibited as cell proliferation are required for both

Magshield Box

Figure 2



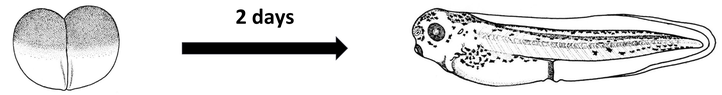
- Helmholtz coils produce magnetic fields of different strengths based on the applied current.
- Both the Earth's normal and near-zero magnetic fields will be verified using multiple gaussmeters to measure magnetic field strength.

Figure 2. Setup for the magnetic shield (MagShield) box. **(A)** Experimental setup of the magnetic shield box (door is closed for experiments), with DC power supply boxes to the left. Earth's normal MF and 0MF chambers are separated by a sheet of mu metal. **(B)** Set up for the Helmholtz coils. Embryos will be placed on positioning stack. *Y*-axis coils in orange. *X*-axis coils in purple.

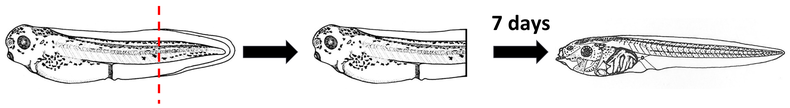
Assays

Figure 3

Development: 2-cell stage embryos are placed in the magshield box and analyzed at the 24-, 36-, and 48-hr time points, comparing the effects of 0MFs to Earth's normal.



Regeneration: Stage 40 tadpole tails are removed and placed in the magshield box. Ability and quality of tail regeneration will be observed and compared to Earth's normal at 1, 3, 6, and 24hr time points. Time and ability for wounds to heal will be compared to Earth's normal.



Wound Healing: Stage 25 embryos are bisected in half and placed in the magshield box. Wound sizes are observed and measured at 1, 3, 6, and 24hr time points. Time and ability for wounds to heal will be compared to Earth's normal.

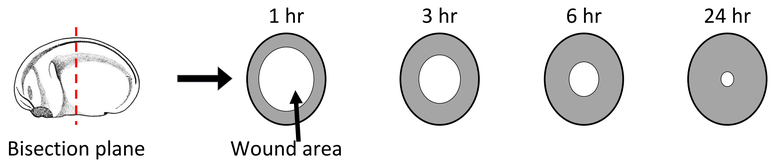


Figure 3. Depictions of assays to be done with Xenopus embryos and tadpoles to test the effect of near-zero magnetic fields.

Summary

- Space magnetic fields are near zero µT
- We successfully constructed a Magshield box that enables the specific control of magnetic field strengths in the two interior chambers.
- Using a gauss meter, we confirmed that the Helmholtz coils can be used to generate 45 µT MF. When the Helmholtz coils are inactive, the chamber showed near zero MF.
- We will compare the effects of changes in magnetic fields of a whole living organism, *Xenopus*.

Selected References and Acknowledgements

- Kinsey, L. et. al. (2023) Weak magnetic fields modulate superoxide to control planarian regeneration. Front. Phys. 10. doi:10.3389/fphy.2022.1086809
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