Understanding vertebrate embryonic development under conditions present in outer space

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Abstract

It is currently unknown whether humans can survive and thrive in outer space, which includes human embryonic development. In this study we investigate vertebrate embryonic development under conditions present in outer space including microgravity and an altered day-and-night cycle using zebrafish and chicken model systems. Zebrafish and chicken model systems are widely used in developmental biology research given their similarity as vertebrates to humans. We aim to analyze the development of brain, muscle and other tissues under conditions of microgravity in both zebrafish and chicken embryos. Additionally, we will analyze zebrafish development under an altered day-and-night cycle (16 sunrises and 16 sunsets per day), and determine whether adult zebrafish can survive and reproduce under these conditions. Zebrafish and chicken embryos will be placed onto a clinostat, which is a device used to simulate a microgravity environment. Embryos will be harvested between 2 and 14 days of incubation on the clinostat, and markers of cell proliferation, death, and differentiation will be analyzed on tissue sections of the brain, skeletal muscle, and other tissues. We expect that our results may allow us to better understand embryonic development under conditions present in outer space, which may shed light on this process in humans.

Background

Scientific breakthroughs enabled us to go deeper into space and have allowed us to live in locations like the International Space Station, far beyond Earth's surface. This has sparked global interest in not just space travel but a newfound fascination with colonizing other planets, like Mars. A proper civilization must have the ability to sustain itself and without an ability to reproduce viable offspring, this cannot occur. However, it is not well-known if humans will be able to reproduce, survive, and thrive in space. This study hopes to begin answering these questions.

https://www.freepnglogos.com/images/mars-18087.html

The above image of Mars is used as scientists and researchers look for future colonizations of other planets. Mars is a great model for future colonization efforts, as it provides the most similar conditions that we experience here at home.

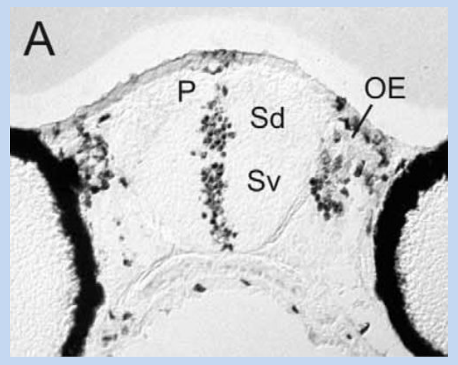
I. Model systems

We used zebrafish and chicken embryo for model systems in this study

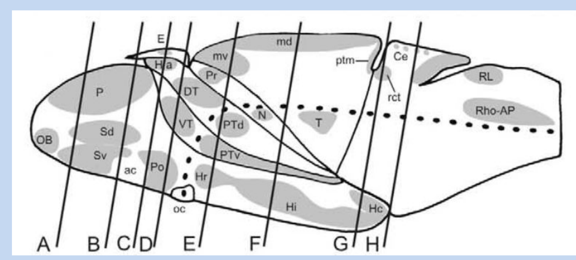
A. Zebrafish

Stages of Zebrafish Development

By Ed Hendel - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=37054608



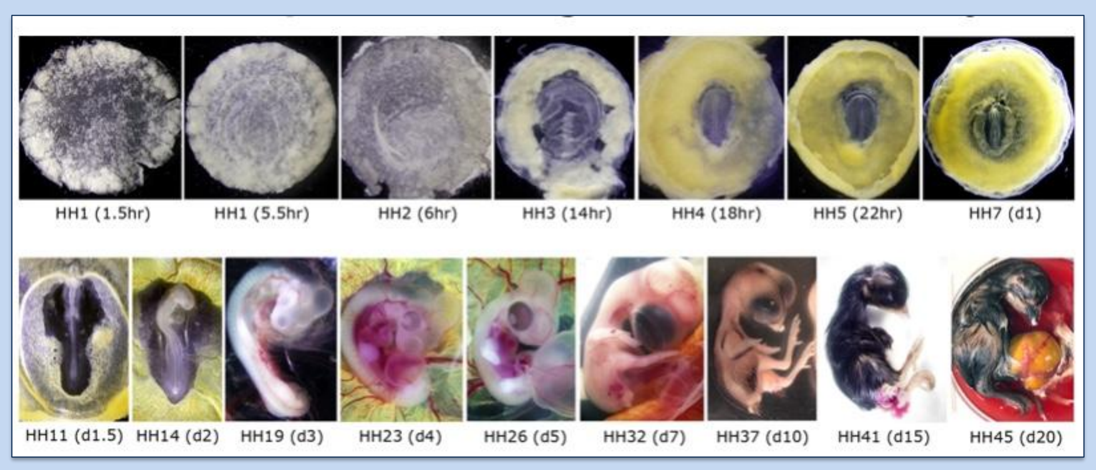
Coronal section showing BrdU labeling in 5 dpf larval zebrafish telencephalon (Mueller and Wullimann, 2002).



Schematic drawing indicating proliferative zones (identified using PCNA labeling) in the larval zebrafish brain (5 dpf) (Mueller and Wullimann, 2002).

B. Chicken Embryo

Chicken embryos are an important model system when studying human brain development as they share anatomical and functional similarities to the human brain.



Developmental stages of chick embryo

(Lizio, et al. 2017)

II. Experimental Manipulations

A. Microgravity simulation using clinostat

Effects of microgravity on zebrafish and chicken embryo were examined by using a clinostat. A clinostat uses a slow rotation on the horizontal axis, which reduces the gravitational pull on the sample, mirroring a zero gravity environment similar to that in outer space.

A clinostat similar to that used in the experiment.
https://edulab.com/product/clinostat-electric/

B. Altered day-and-night cycle on zebrafish development

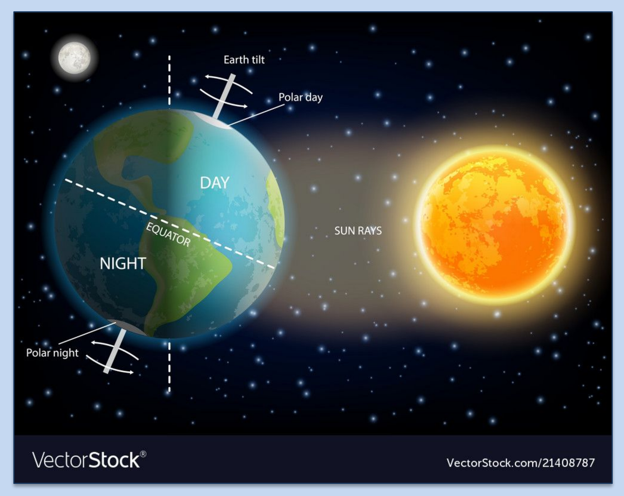


Figure of light/dark cycle
(16 sunrises and 16 sunsets per day)

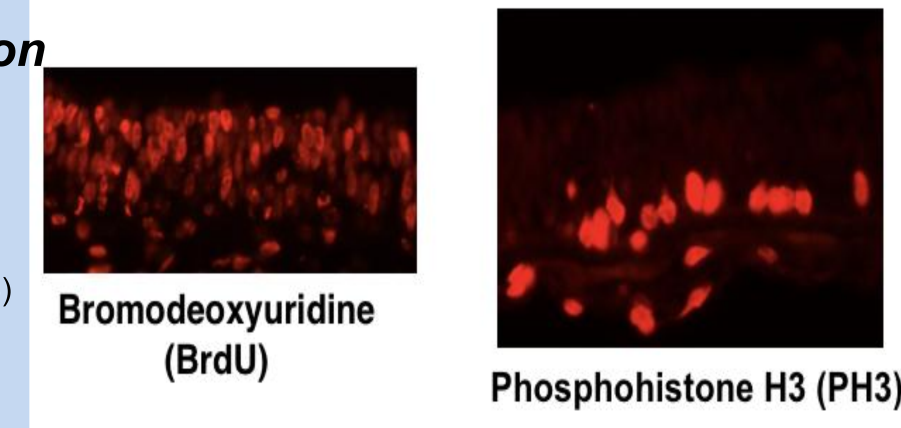
https://www.vectorstock.com/royalty-free-vector/day-and-night-cycle-diagram-vector-21408787

We will be testing zebrafish embryonic and larval development under conditions of an altered day-and-night cycle. We will also be testing whether adult zebrafish can survive, are healthy, and can reproduce under these conditions.

III. Effects on Embryonic Development

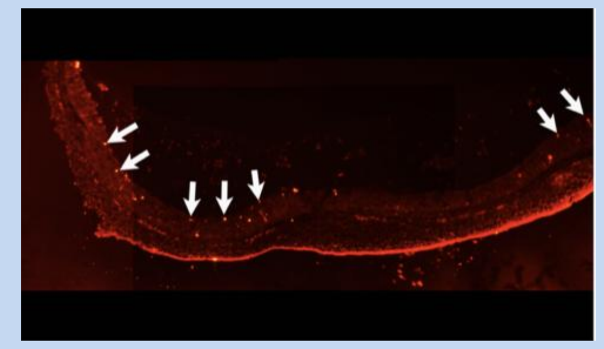
A. Proliferation

(Nakamoto et al, 2014)

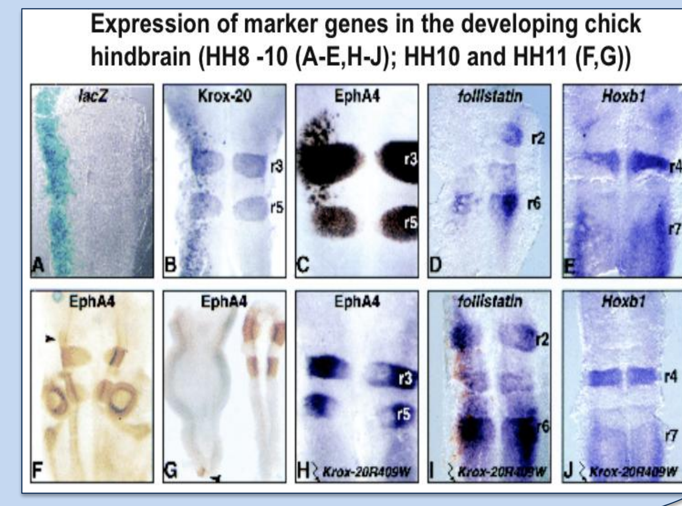


B. Cell Death - Tunel Assay

(Nakamoto et al, 2014)



C. Differentiation



Conclusions & Future Directions

Our results will provide initial insights into how the environment of outer space will affect vertebrate development. Specifically, we will determine the effect of microgravity and altered day-and-night cycle on cell proliferation, cell death, and differentiation in zebrafish and chick embryos. In future studies, we will dissect molecular mechanisms and signaling networks involved in responses to the altered environment in space. We expect that our research will help us address the challenges of deep space exploration and benefit human health in space.

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