It's Alive (Or is it?): Life Science Experiments for High-Altitude Ballooning

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Most HAB student research focuses on the physical sciences and engineering. However, balloon flights can also support important learning outcomes in the life sciences at both the K-12 and introductory college level. For example, inheritance and variation of traits is one of the four life science disciplinary core ideas emphasized in the Next Generation Science Standards[1]. Student experiments can address this idea by exposing microorganisms and plant seeds to the near-space environment. We aim to provide useful information for ballooning educators wishing to engage their students in life science experiments by presenting laboratory protocols to assess survival and mutation rates of *Saccharomyces cerevisiae* (baking and brewing yeast), *Raphanus sativus* (garden radish) and *Brassica Rapa* (Wisconsin Fast Plants®). These protocols can easily be reproduced in K-12 and college classrooms without the need for additional specialized equipment.

I. Introduction

HAB experimentation with plant seeds and yeast can address several key concepts in The *Next Generation Science Standards*[1]. For example:

Life Science 3: Inheritance and Variation of Traits

- Structural changes to genes may result in changes to the structure and function of an organism and change its traits.
- Inheritable genetic variations may result from mutations caused by environmental factors such as radiation.

Life Science 4: Biological Evolution: Unity and Diversity

- Natural selection leads to adaptation of populations.
- Changes in environmental conditions can result in increases in the number of individuals of some species and the extinction of others.

HAB instructors interested in engaging students in investigations with seeds and microbes can take advantage of existing curriculum resources developed by NASA and others that focus on irradiation during space flight, by germicidal ultraviolet light sources and by nuclear radiation. These include, for example, the *Tomatosphere*[2] project, which distributes tomato seeds that orbited Earth aboard the International Space Station for nearly two years to thousands of teachers. The curriculum resources available on the *Tomatosphere* web site were developed for students from grades 2-10 and include investigations of the effects of exposure to the space environment on germination and growth of tomato plants. At the high school level, the *NASA Radiation Biology Educator Guide*[3] contains investigations in which students expose yeast to ultraviolet light from the sun and experiment with seeds that have been irradiated by cobalt-60 sources. A *Classroom Guide to Yeast Experiments*[4], which is available on the Kansas State University Physics Department web site, consists of six activities in which students investigate mutation and survival rates of yeast that has been exposed to germicidal ultraviolet light sources.

In this article we describe two HAB laboratory procedures we have developed, in part, with students during a general education college science course that took place during the spring quarter 2014. They are based on a strain of *Saccharomyces cerevisiae* (common baking and brewing yeast) developed at Kansas State University for student experiements, *Raphanus sativus* (garden radish), and *Brassica Rapa* (Wisconsin Fast Plants®).

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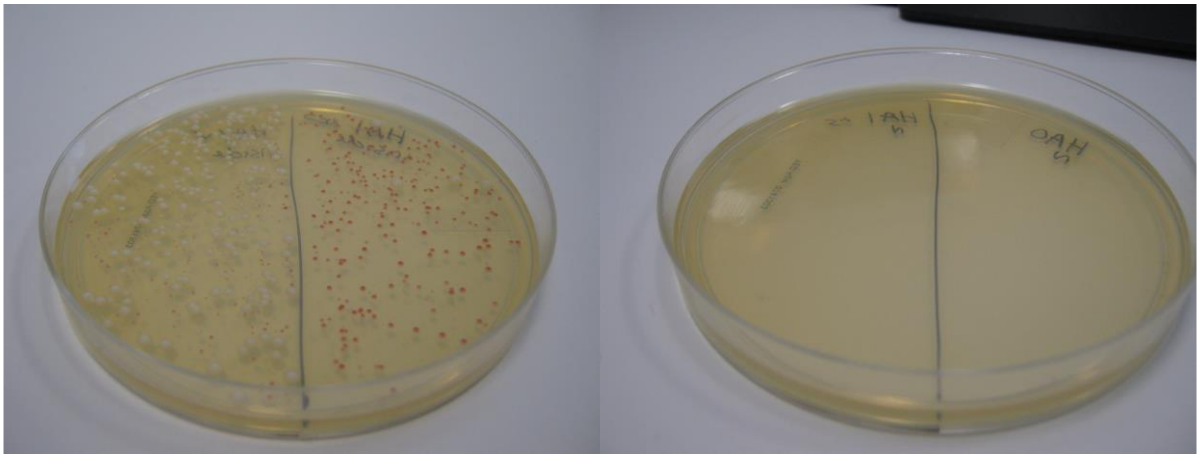

Figure 1: HA1 yeast colonies that were flown on the inside of the payload container show higher mutation rates than the control, as is evidenced by the larger number of cream-color colonies on the left side of the left plate. Yeast flown on the outside did not survive on any of our flights (right plate).

C. Results

Plant seeds: After the flight students should plant their seeds, place them in a location with sufficient light, and regularly water them. To assess the effects of the near-space environment students can quantitatively evaluate a variety of traits related to reproductive rates and phenotypic traits, such as germination rate, plant height, weight, number of flowers and seed pods and seed pod size. In our experiments we found that the near-space environment had no effect on germination rate, i.e., near-100% germination rates for seeds flown on the inside and outside of the payload containers. We analyzed number of flowers and seed pods and length of the longest seed pod using ANOVA statistics. For all three traits the seeds flown on the outside had the lowests averages. To identify potentially interesting mutations, we computed the coefficient of variation for each trait, which is defined as the standard deviation divided by the mean. In all cases this coefficient was largest for seeds flown on the outside.

Figure 2: Radishes and Wisconsin Fast Plants® grown from seeds that were flown on the inside and outside of payload cotainers and from control seeds.

Yeast: Our students who completed this experiment in spring 2014 found that there was little visible difference between the control sample and the sample that flew on the inside of the payload container. In contrast, none of the yeast that was flown on the outside were it was exposed to ultraviolet light and colder temperatures survived. On previous flights we found variable survival rates on the inside, with higher mutation rates for samples with lower survival rates. Because low temperatures do not cause mutations, this suggests that the survival rates are mainly determined by cosmic rays, not temperature. There are many other possibilities for yeast experiments with HA1 and other strains. Students and instructors can find several ideas in *A Classroom Guide to Yeast Experiments*[4].

Conclusion

Students in our HAB courses often express interest in life science experiments. For instructors whose background is in the physical sciences, working with students on plant seed and microbe experiments is an opportunity to connect with colleagues in the life sciences and involve them in HAB. Even without this support instructors can engage their students in life science experiments in a meaningful way without investing large amounts of additional preparation time by adapting existing curriculum resources. We found this to be an enriching experience for both students and instructors.

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