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

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DePaul's HAB Program

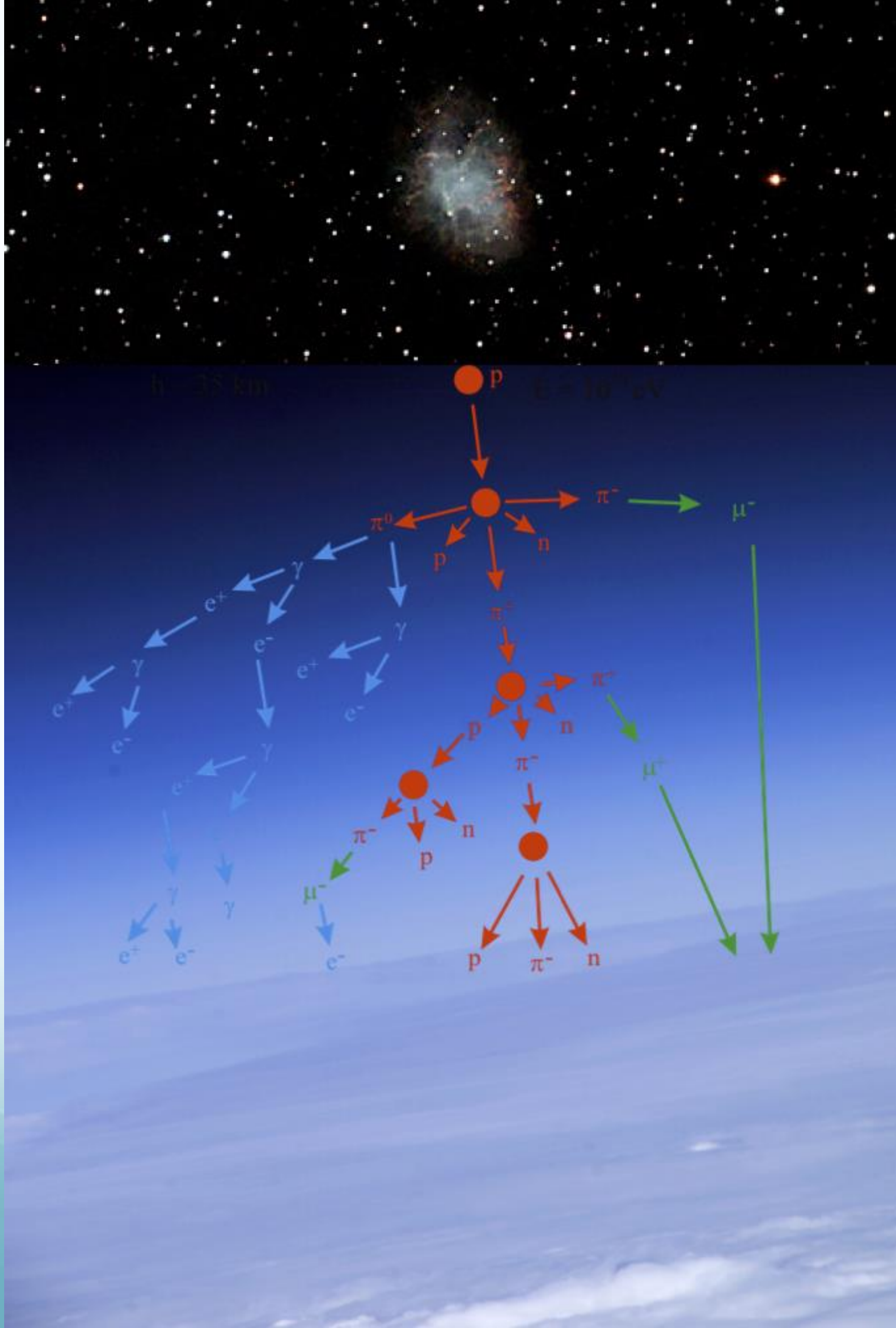
46 flights since March 2009.

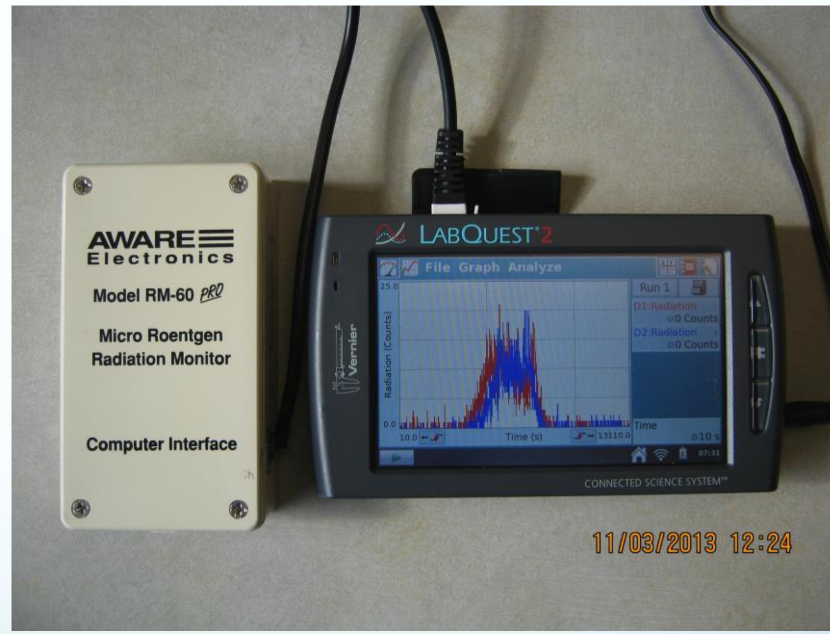
- undergraduate summer research (11)
- environmental science senior thesis projects (13)
- atmospheric chemistry course (2)
- Society of Physics Students (4)

- community college faculty workshops (2)

➢ general education courses (6)

➢ high school and middle school outreach (8)

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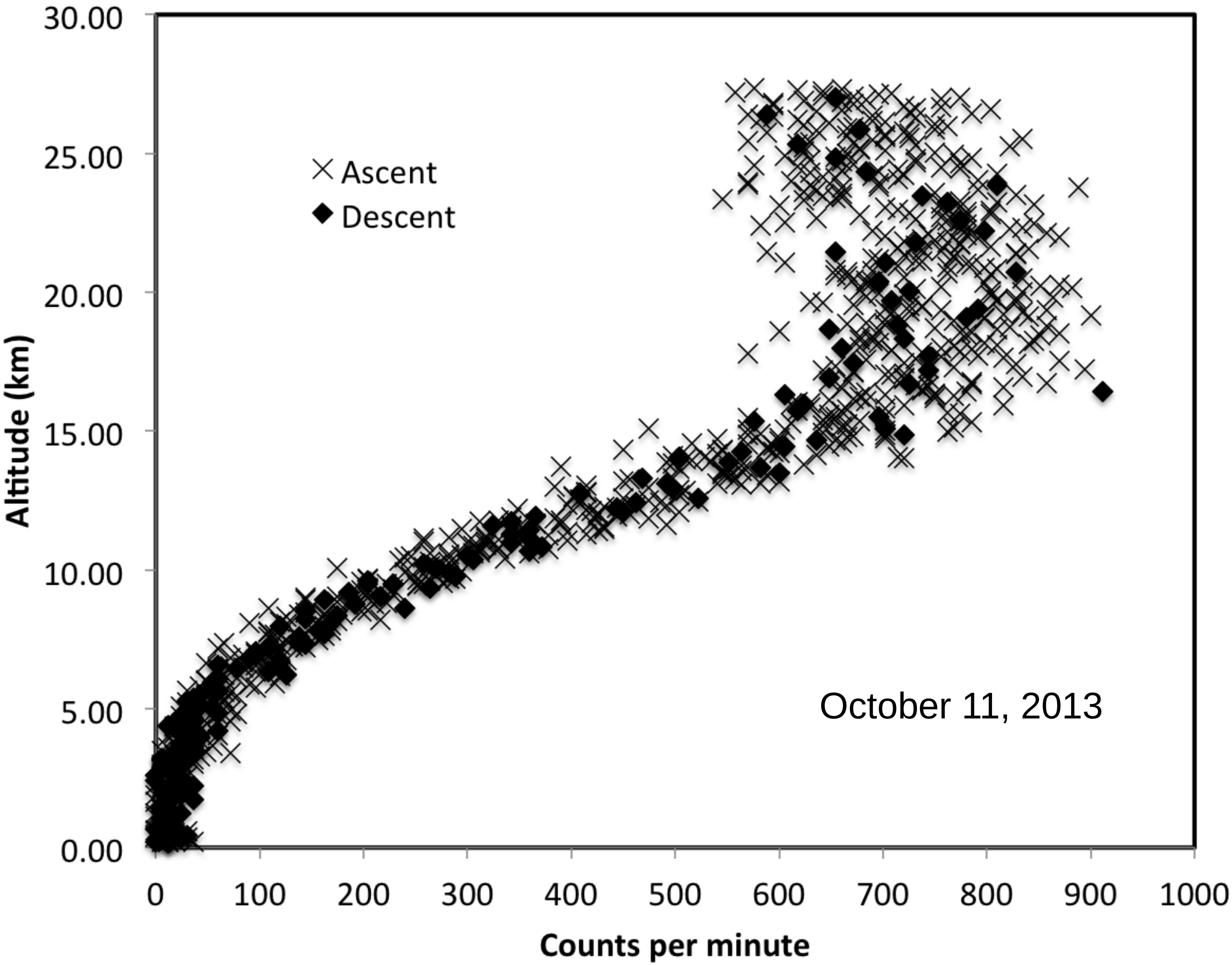
Model RM-60 PRO
Micro Roentgen Radiation Monitor
Computer Interface
LABQUEST 2
File Graph Analyze
CONNECTED SCIENCE SYSTEM™
11/03/2013 12:24



30.00
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15.00
10.00
5.00
0.00
Altitude (km)
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300
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700
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900
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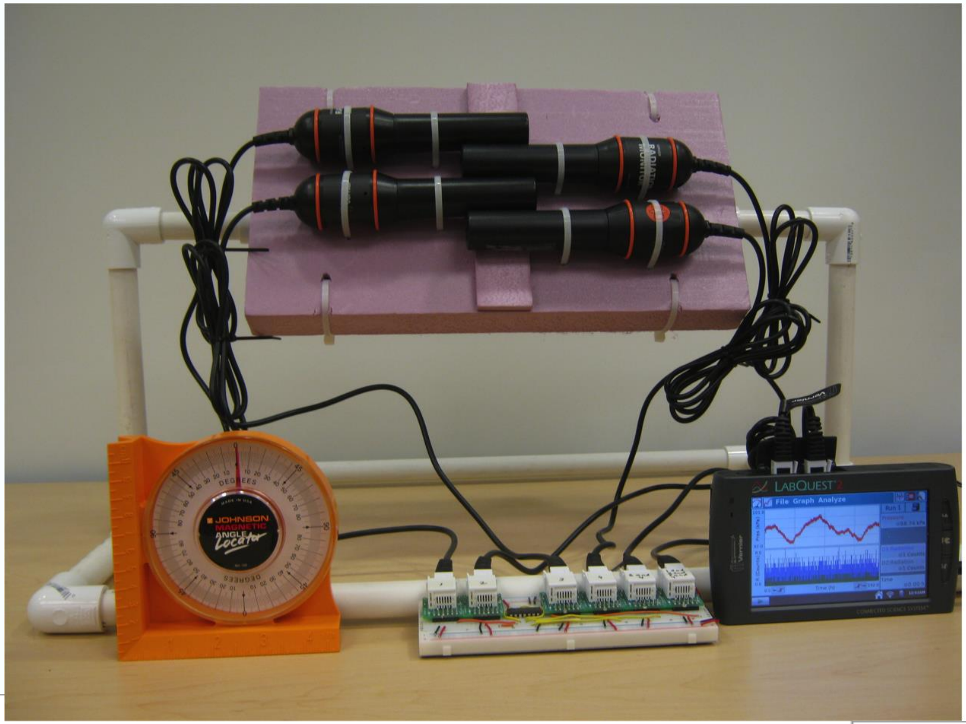
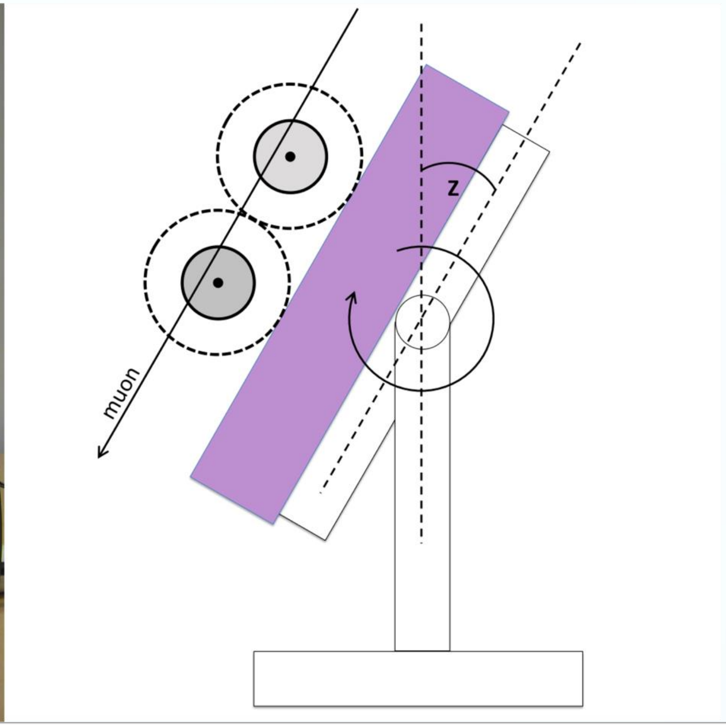
Ascent
Descent
October 11, 2013

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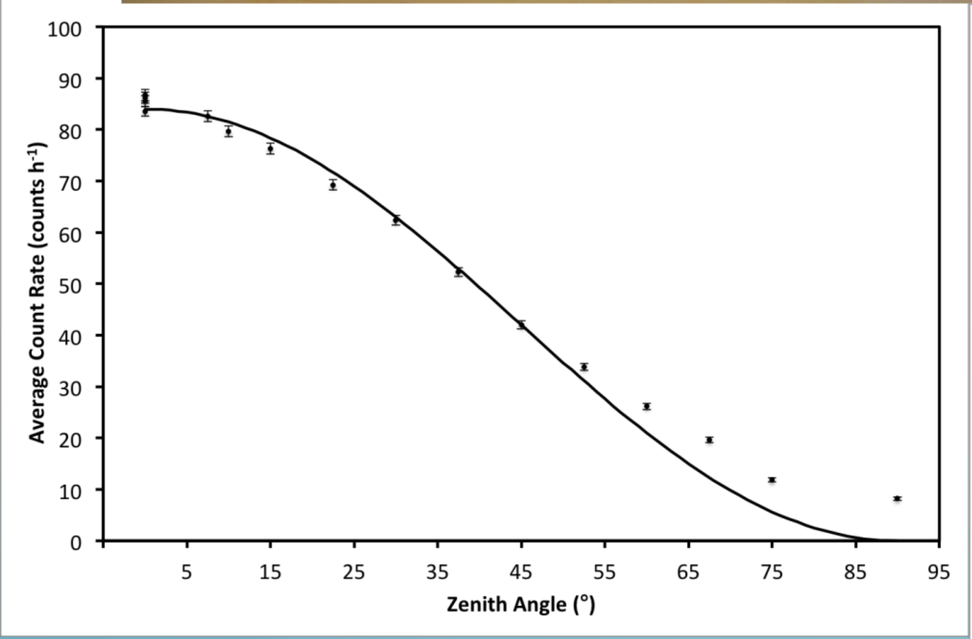
Average Count Rate (counts h-1)
Zenith Angle (°)
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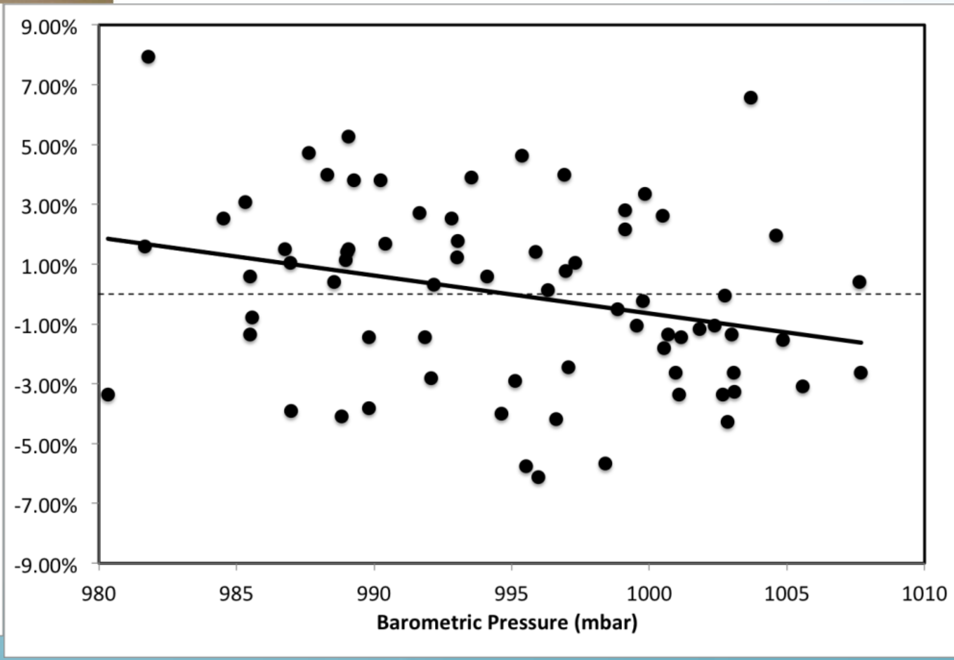
Barometric Pressure (mbar)
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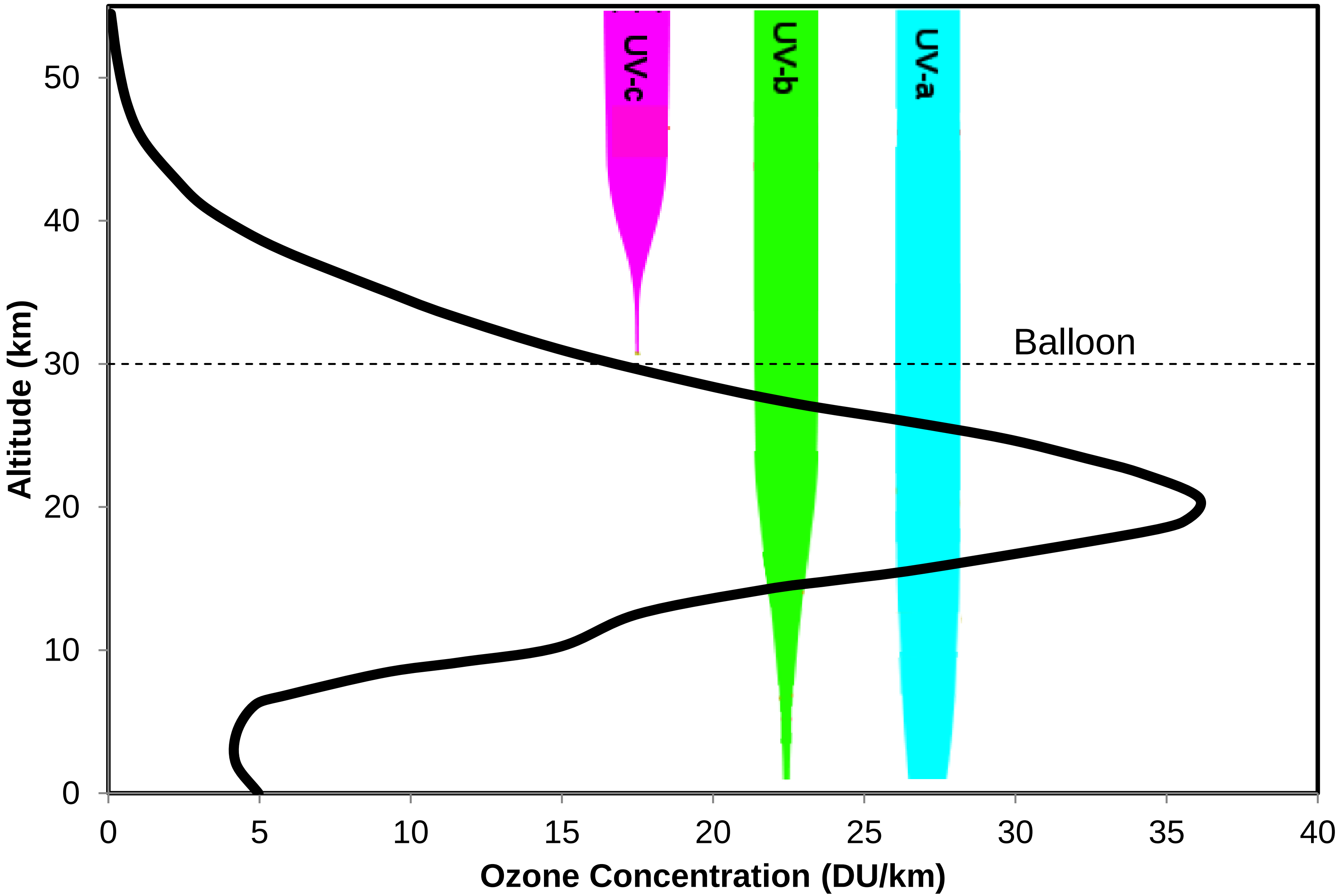

SAGE III Ozone Loss and Validation Experiment
https://cloud1.arc.nasa.gov/solve/

K-12 Curriculum

Student investigations of the effects of radiation on microbes and seeds during balloon flights address central ideas in the K-12 curriculum.

NGSS LS3 Heredity: Inheritance and variation of traits

NGSS LS4 Biological evolution: Unity and diversity

- Effects on structure and function.
- Survival and reproduction.
- Natural selection.
- Genetic engineering.
- Environmental factors.
- Evolution.
- Statistical analysis of populations.

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Space Microbiology

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Cospar, Vienna, May 1966

The Survival of Microorganisms in Space
Further Rocket and Balloon Borne Exposure Experiments

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Advances in Space Research 48 (2011) 1155–1160

Advances in Space Research
(a COSPAR publication)
www.elsevier.com/locate/asr

Viability of barley seeds after long-term exposure to outer side of international space station

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PERGAMON

Available online at www.sciencedirect.com
ScienceDirect
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ACTA ASTRONAUTICA
www.elsevier.com/locate/actaastro

Spaceflight effects on consecutive generations of peas grown onboard the Russian segment of the International Space Station

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SURVIVAL OF MICRO-ORGANISMS IN SPACE

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A BALLOON EXPERIMENT TO DETECT MICROORGANISMS IN THE OUTER SPACE

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GROWTH PROTOCOLS FOR ETIOLATED SOYBEANS GERMINATED WITHIN BRIC-60 CANISTERS UNDER SPACEFLIGHT CONDITIONS

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Summary of Biological Spaceflight Experiments with Cells

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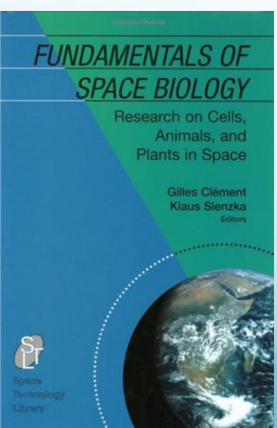
Space Med Med Eng (Beijing). 1997 Apr;10(2):79-83.

Mutation effect of high altitude balloon flight on rice and green pepper seeds.

Li J[1], Wang P, Han D, Chen F, Deng L, Guo Y.

Achievements and Perspectives of Crop Space Breeding in China

L X Liu, H J Guo, L S Zhao, J Wang, J Y Gu & S R Zhao



NASA/TM-2009-214768

Roadmaps and Strategies for Crop Research for Bioregenerative Life Support Systems
A Compilation of Findings from NASA's Advanced Life Support Meetings

高空环境对水稻遗传性的影响

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Effect on Rice Genetical Character by High Space Condition

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Crop Production for Advanced Life Support Systems –
Observations From the Kennedy Space Center Breadboard Project

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Advances in Crop Improvement by Space Mutagenesis in China

Lu-xiang Liu[1], Hui-jun Guo, Linshu Zhao, Jiayu Gu and Shirong Zhao

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Microbe research

- Model organisms for evaluating biological responses.
- Detecting life on other planets.
- Avoid contamination of other planets.
- Origin and spread of life.

Plant seed research

- Plants for long-duration space travel.
- Mental well-being of astronauts.
- Plant breeding.
- Spread of life.

No need to start from scratch!

Existing curricula use

- ultraviolet light from germicidal light sources and the sun to irradiate yeast and other microbes.
- seeds that were irradiated with gamma rays from cobalt-60 sources, which are available from science supply companies
- seeds that were irradiated with cosmic rays during orbital flights.

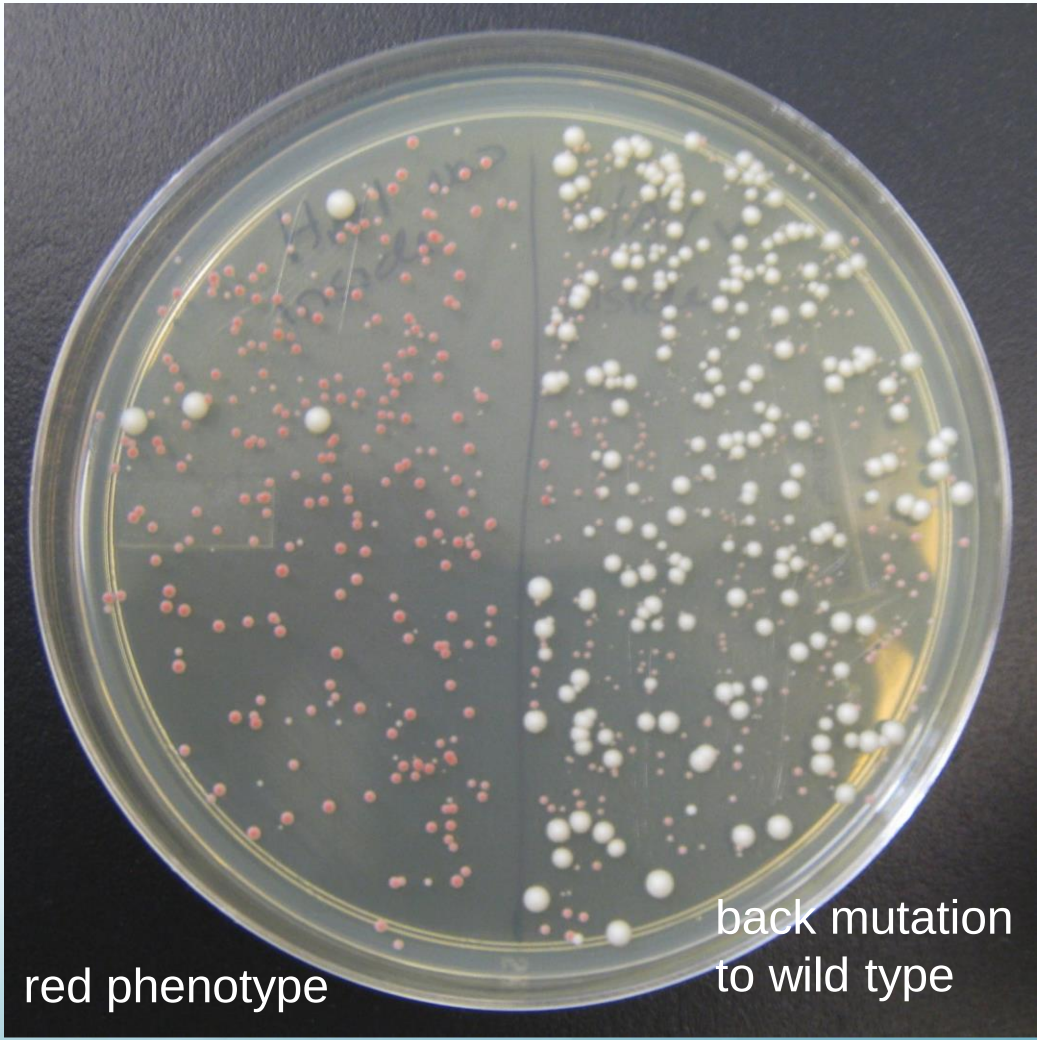
Examples:

- NASA Radiation Biology Educator Guide
- A Classroom Guide to Yeast Experiments
- Tomatosphere project
- NASA's Lunar Plant Growth Chamber

Yeast strains

Baking and Brewing Yeast (Saccharomyces cerevisiae)

- HA1 and HA2 strains contain mutations that cause cells to turn red. Back-mutations to the white wild type are easy to spot.

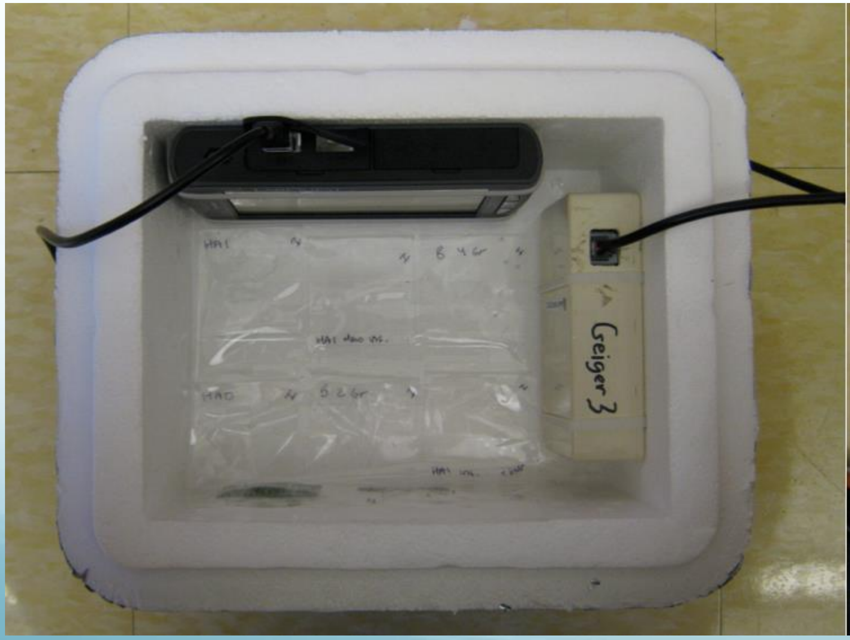


From Manney et al. “A Classroom Guide to Yeast Experiments”.

Simple procedures

Pre-flight

- Transfer small sample into sterile water.
- Pack 1-2 ml of yeast suspension into 5 cm square zip lock bags.
- Tape bags to the inside and/or outside of payload containers.



Post-flight

- Spread yeast suspension with sterile swab evenly on sterile media plate.
- Incubate for three days at 30°C. (Can also be done at room temperature if incubator is not available.)
- Determine survival and mutation rates by examining plates visually for colony number, color, size and shape.

Balloon Launch May 17th 2014

Vanessa Cadavillo & Rebecca Quade

HON 225, Professor Beck-Winchatz

ABSTRACT

We often hear theories on how radiation affects human life and DNA. This experiment observes the intensity of cosmic radiation and UVA/UVB rays in space on yeast, which is a model organism for human beings. Thus, observing the difference in levels of radiation and UVA/UVB rays from Earth to the edge of space, as well as its possible effects on the organism allows us to gain knowledge on whether or not the exposure is dangerous for humans. According to our findings, the levels of radiation are not extreme enough to cause any negative side effects, however, the UVA/UVB rays could be a contributor to stunting regular growth patterns of yeast and also human DNA.

BACKGROUND

NASA has done multiple studies on the effects of radiation on living organisms. In order to keep astronauts safe and healthy during long duration space missions, scientists must gather as much information as possible on the probable side effects of radiation exposure. The risks are described in the "NASA Bioastronautics Critical Path Roadmap, and include carcinogenesis, acute and late central nervous system risks, chronic and degenerative tissue risks, and acute radiation risks" (NASA). In order to protect the astronauts during long duration space travel we need to further understand how the radiation effects the human body. It is not yet possible to avoid the radiation completely, however, studying the results of experiments such as this one can allow NASA to adequately develop protective space suits.

Microbiologists often use yeast as a model organism for human beings. The DNA strands are so similar that the results of studies done on yeast can be extrapolated and utilized in studying the effects on human DNA. HA1 yeast strains, created at Kansas State University, were specifically created to test the growth of mutations which is why this strain was used in our study. Because their DNA strand mimics that of humans, the results allow people to juxtapose the two organisms and their reactions to radiation or other kinds of exposure.

PURPOSE

The purpose of this experiment was to observe the effects of radiation on life form similar to that of humans. Then the data can be extrapolated in order to further our knowledge on the effects of space travel on astronauts. Due to the fact that we could not bring up a human or animal into space, we used yeast as it closely resembles the human DNA. We wanted to see what would happen to the yeast if brought to space and what negative or abnormal effects would occur such as altering the growth, shape, or color of the yeast. Furthermore, we wanted to compare the radiation differences within the edge of space and Earth. This will allow us to infer what kinds of mutations could be cause due to space travel that are not as common on Earth because of the lower levels of radiation and UVA/UVB that we as humans experience on a daily basis.

Above every square inch of body, there is 14 and a half pounds of air above in the atmosphere. This is the amount of mass that a space craft would need to be constructed with in order to protect astronauts from being exposed to the high levels of radiation present in space. This experiment aims to compare the levels of radiation and UVA/UVB recorded on Earth with the data collected during the flight to deem whether the exposure is harmful enough to cause negative side effects.

MATERIALS AND METHODS

Materials:

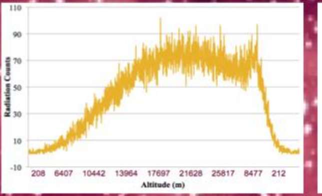
- Petri dishes
- Medium nutrient
- HA1 yeast strings
- Cotton swabs
- Incubator
- Small plastic bags
- Thermometer
- Beakers
- Radiation sensor
- UVA & UVB sensors

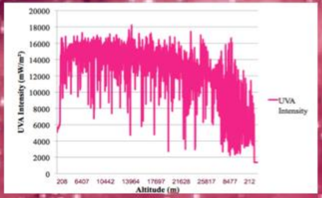
Method:

In preparation for the flight, we observed the growth of yeast in four different tests. By doing this, we were able to see what the normal growth of yeast and mutant colonies. Yeast turns into a red-pinkish color once it is at it's full growth and no longer receives the nutrients from the medium. Mutants within the yeast turn a white color and can continue to growth even without the medium. Out of the four tests the first test and the last (post-flight) were the most successful. The yeast turned into a pink color and showed visible growth as well at the mutant colonies. We suspect that it could have been the use of a different incubator which affected our tests in between.

For the flight, we prepared the yeast in tiny bags. We made a total of six bags: two were taped inside the pod, two were taped on the outside of the pod, and two were left back and used as controls. We made two bags each because we were unsure at the time if the yeast in the vial was still alive, so we used yeast from the first successful growth and yeast from the vial to be thorough.

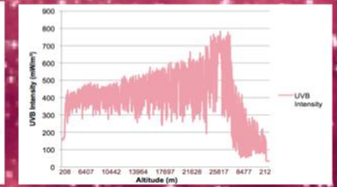
As for the collection of data, we set the sensors to collect data every six seconds within the duration of the flight. We did this in order to get an abundant amount of data to make our data more precise. Once we returned from the flight, we swabbed the yeast onto the Petri dishes and inserted them into the incubator at body temperature (37°C).





Data Analysis

The above graphs show the correlation between altitude and radiation as well as altitude and UVA/UVB intensity. As expected, all three types of exposure increase as altitude increases. At the highest level of radiation during the flight, it was approximately 50 times higher than on Earth. The UVA at its highest was approximately 6 times higher and the UVB at its highest was approximately 12 times higher than the level we measured on Earth. The radiation counts and the UVA/UVB rays are both potential contributors to negative side effects from space travel. These graphs will enable us to infer whether or not the exposure is strong enough to produce the possible side effects.



RESULTS

We have various results to examine. First, the UVB and UVA sensors showed that the intensity of those rays are exponentially higher than on Earth. The same pattern existed with the radiation count.

As for the petri dishes, we noticed a few strange growths that didn't align with the previous petri dishes. The growth of the pink yeast, which need nutrients to grow turned out far bigger than the white mutations. Usually, the white mutant colonies would appear bigger than the pink colonies as they do not need nutrients to grow. In all the petri dishes, including the control groups, there were significantly more white mutations compared to red yeast growth. This lead us to believe that there was not an impact from the cosmic radiation in space to the natural growth of yeast and that the white growths might be due to something that had developed in the original strain of yeast. There was not a significant difference in the number of mutants in comparison to the control groups. This could be due to the fact that our experiment was only capable of reaching the edge of space rather than deep space.

In addition, the samples that were sent into space on the outside of the box showed no sign of growth whatsoever which could indicate multiple findings.

From left to right: 1A sample that was launched on the inside of the payload, 1B sample that was launched on the outside of the payload, and 1C sample that is the control and was not launched at all.

CONCLUSIONS

The flight and project as a whole has helped us to better understand the impact cosmic radiation and UVA/UVB rays have on life form. While there could have been confounding variables that existed through this process such as human error, data collection error, or contamination, the ratios of white to red growths on the Petri dishes did not differ significantly from control to the samples that were in space. We conclude that the radiation levels were not high enough at the edge of space to cause any visibly noticeable side effects to the yeast. However, due to the fact that the samples exposed directly to UVA & UVB showed no sign of life at all, it is possible that the levels were high enough to kill the strain.

REFERENCES

1. NASA, "The Radiation Reference", http://www.nasa.gov/pdf/284274main_Radiation_HS_Mod2.pdf
2. Parker, Eugene N. "Shielding Space Travelers", http://www.sciam.com

Results from our students

- Yeast flown on the outside does not survive.
- Yeast flown on the inside have variable survival rates.
- When survival rates are high mutation rates are low and vice versa.
- Many interesting questions for students to investigate.

Seeds for balloon flights

Garden radish (Raphanus sativus)

- Germinate quickly.
- Allows you to quickly make quatitative measurements (germination rate, root length, etc.)
- Ideal for younger kids.

Wisconsin Fast Plants (Brassica rapa)

- Short life cycle (40 days).
- Allows for multigenerational studies to look for heritable mutations.
- Ideal for high school and beyond.

Results from our students

- Near 100% survival rates
- Seeds exposed to cosmic rays and ultraviolet radiation on the outside have lowest reproductive rates. (Number of flowers and seed pods.)
- Larger variation for every measured trait. (plant height, weight, etc.)

Reproductive rates and phenotypic traits of Brassica plants.

Plant	Number of flowers			Number of seed pods			Length of longest pod (cm)		
	Control	Inside	Outside	Control	Inside	Outside	Control	Inside	Outside
1	3	4	2	0	1	0	1.5	3.5	4
2	3	4	3	0	2	0	2.5	3.5	3.5
3	3	5	3	1	1	0	1	2.5	2
4	3	4	4	3	1	2	1	0.5	3
5	5	3	4	2	1	1	0.5	1	1.5
6	3	3	5	1	1	1	1.5	0.5	0.5
7	4	6	3	1	0	0	4	2	0.5
8	5	4	4	1	0	1	2.5	1	0.5
9	8	3	5	0	0	0	2	1.5	1
10	6	6	4	1	0	0	2	3.5	0
11	5	5	1	2	2	0	0.5	3	0
12	4	4	0	0	0	0	2.5	3	0
Average	4.33	4.25	3.17	1.00	0.75	0.42	1.79	2.13	1.38
CV	0.36	0.25	0.44	0.95	1.01	1.60	0.56	0.56	1.04

Simple statistics:

- ANOVA
- Coefficient of variation = standard deviation / mean

Questions?