Volume 10, No. 1 **Summer 1997**

WISCONSIN FAST PLANTS notes BOTTLE BIOLOGY WISCONSIN

Scientists Announce First-Ever Germination Of Seeds Grown In Space

Another Milestone for Fast Plants!

AUGUST 9, 1997 - Scientists have reported that for the first time, seeds planted in space have produced seeds that subsequently germinated. Scientists hailed this week's development on the Russian space station Mir as a crucial first step to eventually growing multiple generations of plants in space. Space Shuttle Atlantis delivered seeds of the *Brassica rapa** plant to Mir last May. *Brassica rapa* is a close relative of broccoli, cauliflower and Brussels sprout plants.

> **"... it's the first time plants have been grown from seed in space and made seed in space that subsequently was planted and able to grow,"**
>
> **- Scientist Mary Musgrave**

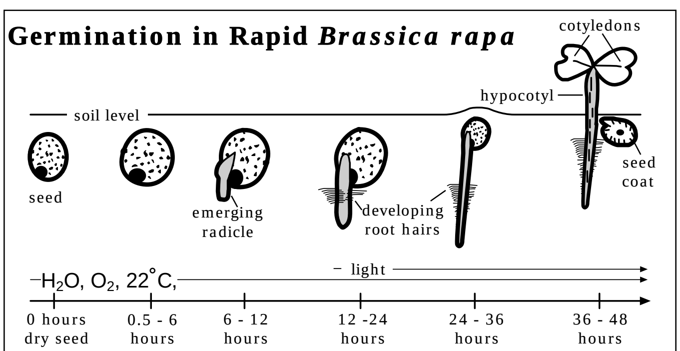
"This is really a historic time for us because it's the first time plants have been grown from seed in space and made seed in space that subsequently was planted and able to grow," said principal investigator Dr. Mary Musgrave of Louisiana State University's Agricultural Center, Baton Rouge. "This seems like a real milestone in plant space biology. My first reaction was feeling really good for the whole group of people who have been involved in this project, and especially good for astronaut Mike Foale, who's done the work of tending the plants for these long months."

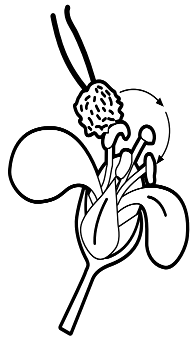
There had been uncertainty as to whether the seeds would be viable after a collision with a supply ship damaged one of Mir's laboratory modules, rendering it useless. The impact and damage sustained by Mir resulted in a power outage, but Musgrave's experiment survived in another module. For almost three days, the tiny plants lay in darkness. This could have doomed the fast-growing plant, Musgrave said, noting that the plant's life cycle from seed to seed is only 45 days. It flowers only 14 days after planting. Seed pods did form, however, and Foale said he could shine a flashlight through the pods and see the seeds inside. This did not, however, answer the question of whether the seeds would grow. "We won't know until the new seeds germinate," Foale said. "There's just no way of knowing what the quality or condition of the seed is."

Researchers from the U.S., England and Russia, including co-investigator Dr. Margarita Levinskikh of the Institute of Biomedical Problems in Moscow, were delighted about the news. "Our experiment has been unique because the plants took the same amount of time to flower and produce seeds on orbit as they do under normal gravity conditions," Musgrave said. "They were able to flower and make new seeds and this means that all of the basic processes that you would hope for a plant to be able to do can happen in microgravity. We hope the project will be able to reach its goal of five months' duration. This would give us time for additional life cycles of the plants."

* *Brassica rapa* - Improved Basic Rapid *Brassica rapa,* Wisconsin Fast Plants

Germination in Rapid *Brassica rapa*





Many of the processes we take for granted on Earth must be taken care of mechanically in space. Foale pollinated the plants by hand, using the thorax of a bee on a small stick to collect pollen and pass it from plant to plant. He also separated the mature seeds from their pods and replanted them by hand in the Russian Svet greenhouse.

Musgrave said that with growing excitement over recent successes in space such as the Mars Pathfinder mission, continued Space Shuttle flights and the multitude of extended projects such as her Greenhouse-3 experiment aboard Mir, interest in interplanetary travel is higher than it has been in years. Microgravity experiments such as hers are addressing important questions, she added. "This opens the door for future research with other types of plants that could be used for food and atmosphere regeneration on long-duration missions," Musgrave said.

For near-term application in space, she said people are looking for plants that occupy a small area or volume, that grow quickly and that produce an edible portion without producing a lot of non-edible material. On long-duration missions, she said, it would make sense to use plants as part of a system to provide atmospheric cleansing and water regeneration — life support processes for humans. Plants can provide food at the same time they perform these other functions. It is possible to select plants based on their nutritional qualities and have relatively few plant species that could provide a large portion of the human dietary requirements, she said.

NASA's Ames Research Center, Moffett Field, CA, is providing payload management and science support for the Greenhouse-3 experiment. "This experiment has been the result of a lot of hard work and many months of planning and coordination from an outstanding group of Russian and American scientists and engineers from the Institute of Biomedical Problems in Moscow, Louisiana State University, Utah State University/Space Dynamics Laboratory, the University of Nottingham in England and Ames Research Center," said Paul Savage Jr., chief of Ames' Science Payloads Operations Branch. "We're all really proud of this accomplishment and of what we are contributing to humankind's further understanding of gravitational biology in space."

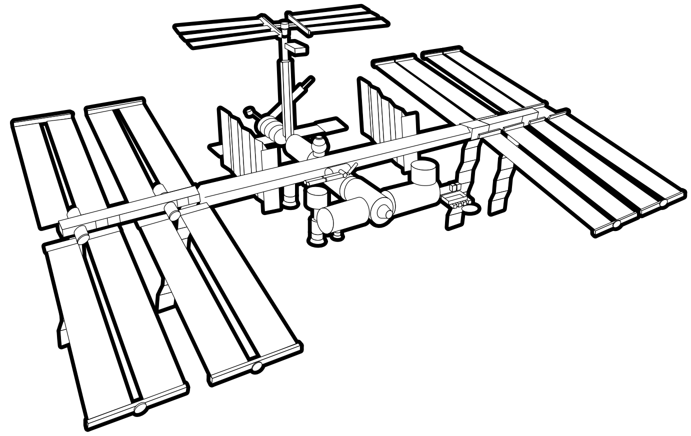
Contributed by Sam Rollason (Louisiana State University, Associate Professor, Agricultural Communications) and Ann Hutchinson (Special Assistant for Public Affairs, Ames Research Center).

"Seed pods did form.... Foale said 'he could shine a flashlight through the pods and see the seeds inside.' This did not, however, answer the question of whether the seeds would grow. 'We won't know until the new seeds germinate,' Foale said. 'There's just no way of knowing what the quality or condition of the seed is.'"

- Astronaut Mike Foale
from the Mir Space Station, 1997

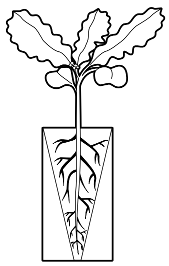
"Though I do not believe that a plant will spring up where no seed has been, I have great faith in a seed. Convince me that you have a seed there, and I am prepared to expect wonders."

- Henry David Thoreau,
Dispersion of Seeds, 1860



The Importance of Plants in Space

Excerpted from the NASA teacher guide, *Teachers and Students Investigating Plants in Space.* Contributed by Bonnie J. McClain (Purdue University Grantee, Education Programs Coordinator, NASA Space Life Sciences) and Tom K. Scott (Senior Scientist, NASA Space Life Sciences).



The relationship between plants and humans has always been a close and interdependent one. Research about basic plant processes helps in understanding and augmenting this interdependence. Ground-based investigations yield information vital to this understanding; however, the knowledge gained from plant research in space is exciting and extends potential for new discoveries beneficial to humans. There is abundant evidence that microgravity affects virtually every aspect of plant growth. Space flight provides the only known environment in which fundamental biological processes and mechanisms can be studied in the absence of the sometimes overriding effects of gravity. Removal of the effects of gravity for long periods of time allows new perspectives in the study of plants.

Answers to important questions about the basics of plant growth and development lie in understanding the role gravity has on plant processes and responses to the environment. For example, gravitropism is the bending response of plants to the force of gravity with the roots growing down-ward and the shoots growing upward. Charles Darwin began experiments on plant gravitropism during the nineteenth century, yet the mechanisms of this process are still not clear. The more knowledge generated about how plants function, the more likely we can adapt that information into practical, useful new applications and products enhancing life on Earth and in space.

Knowledge of physiology, cell biology, biochemistry and molecular biology of plants coupled with biotechnology advances contributes to our fundamental knowledge of plants and provides impetus for a new era of plant investigations. Understanding how basic processes can be manipulated and put into use in new ways that develop new products and increase productivity is the basis for biotechnological applications in agriculture, horticulture, and forestry. For example, understanding the interaction between gravity and light could be the basis for genetic engineering of plants resulting in increased crop productivity while minimizing the required growing space.

Extended duration human exploration missions will require life support capabilities beyond those now available. A solution is to develop technologies that integrate physical and chemical processes into a dynamic, recycling life support system.

Studying plants in space will provide the scientific information necessary for development of such a life support system. Plants will be a primary component of atmospheric regeneration: carbon dioxide exhaled by humans will be taken up by plants and used in photosynthesis, in the process returning oxygen and food to the crew. Plants are also important in water regeneration.
The productivity of plants relative to the input of energy (light) can be increased by using such techniques as carbon dioxide enrichment and hydroponics. To achieve a controlled life support system, ground-based research in growth chamber facilities will be conducted along with plant investigations in the microgravity environment of space flight.

NASA's research with plants in space is dedicated to systematic studies that explore the role gravity plays at all stages in the life of higher plants. Research focuses on the interactions of gravity and other environmental factors with plant systems, and uses hypergravity, simulated hypogravity and microgravity as tools to advance fundamental knowledge of plant biology. Results of the research contribute to NASA's efforts to further human exploration of space and to improve the quality of life on Earth through applications in medicine, agriculture, biotechnology and environmental management.

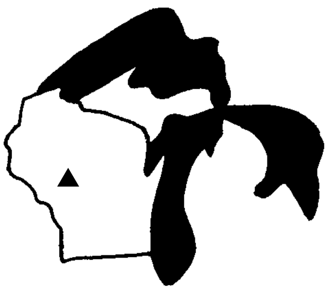
Why study plants in space? The discoveries made, lessons learned, and technologies developed from these investigations will benefit those of us on planet Earth as we unlock and utilize gravity's mysteries to enhance our journey into space.

Fast Plants: A Space Odyssey

A Plant Designer Challenge for and from Students

Newsflash:

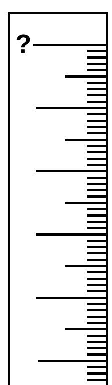
Up in north central Wisconsin where the oak savannah meets the beginnings of the northern hardwoods, the "Gregor Mendel Seed Company" (a.k.a. the students in Paul Tweed's biology classes at Augusta High School) announce that they have been successful in creating a super-plant population of Fast Plants from the AstroPlants stock. AstroPlants average 10 cm in height at 14 days of age; the new Gregor Mendel Seed Company stock is averaging 50 cm and boasting sturdy stems!



But we're getting ahead of our story.

1986: Basic Fast Plants

In 1986, when the Wisconsin Fast Plants were launched into science classrooms, the average height of the plants in flower at 16 days old was 20 cm.

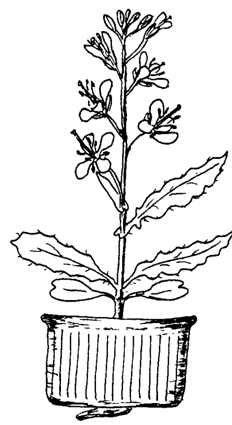


Teachers, however, mentioned concerns that the flowers sometimes crept up into the fluorescent tubes of the light banks and that plants also had a tendency to flop over if they were not staked. The decision was made to develop shorter, stockier plants. By introducing the dwarfing gene (petite, *dwf*1), the basic Fast Plants stock was shortened. Repeated generations of selection were needed to create a vigorous, true breeding petite stock having an average height of less than 10 cm.

1987-1994: The "Washington Shuttle Stock"

During the next 8 years or so with shorter stocks in the making, Paul Williams, the developer of Fast Plants, made frequent trips to Washington, DC, for various education commitments and was often asked to bring some Fast Plants to use for demonstrations.

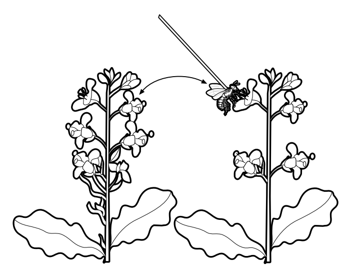
The easiest way to transport up to 65 of the increasingly shorter plants was to grow them in bottle cap wick pots using a five-liter circular Rubbermaid™ cake container and a 30 watt circle light as the transportable growing system.



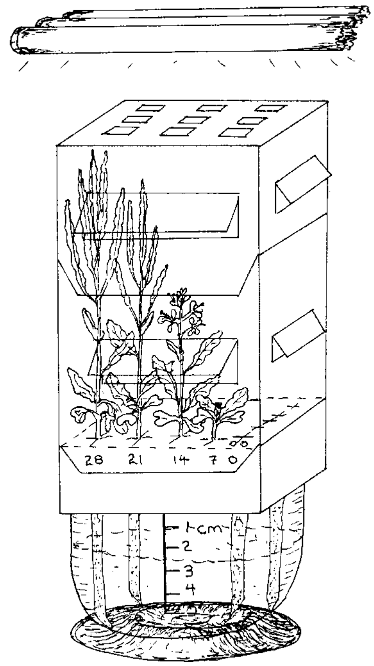
Washington Shuttle Stock in bottle cap wick pot

While in transit, the reservoir was snapped over the top of the plants growing on the lid, providing a stable and protective system for getting the plants safely from Madison, Wisconsin, to Washington and back again. Over successive generations of growth and reproduction on airplanes, in hotel and conference rooms, this stock became adapted to life on the move!

Lots of famous scientists and educators, including Donna Shalala (Secretary of Health and Human Services) and Bruce Alberts (president of the National Academy of Science) to name just two, had a hand in pollinating and parenting succeeding generations of what became known as the "Washington Shuttle Stock."



September 1994: AstroPlants



AstroPlants in simulated Astroculture™ system

The next chapter opens with an engineering group at the Wisconsin Center for Space Automation and Robotics (WCSAR) on the University of Wisconsin-Madison campus. This group had developed an environmentally controlled Astroculture™ Unit for the Space Shuttle, with which scientists could study the influence of low gravity and acceleration forces on plant growth. In February of 1995, the Washington Shuttle Stock plants, renamed AstroPlants, were flown in the Astroculture™ Unit on the Space Shuttle Columbia, STS-63. Across the United States, 13 middle and high school teachers and their students ran simulations of the ground-based control experiments (see Spring 1995 issue of *Notes*).

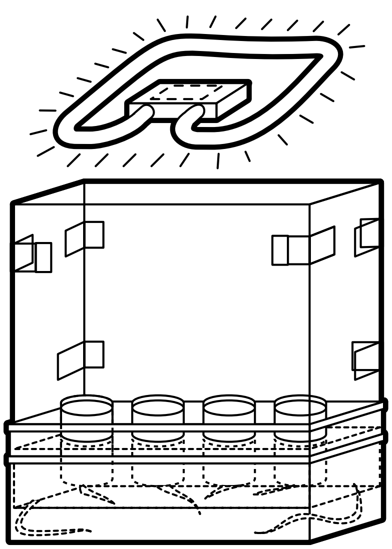
1996-97: AstroPlants for CUE

The AstroPlants have recently completed their second mission. In April, four undergraduates from Louisiana State University, under the direction of Dr. Mary Musgrave, pollinated AstroPlants in microgravity on the KC-135 aircraft during a parabolic flight.

Photos of this KC-135 flight are on the Internet at *http://ston.jsc.nasa.gov/ZeroG/students/xseoG.*

Four different counts were used to quantify pollen transfer: number of pollen grains collected by a beestick; number of pollen grains transferred to a stigma; number of pollen grains transferred per unit of stigma surface area, and number of ovules developing following pollination.

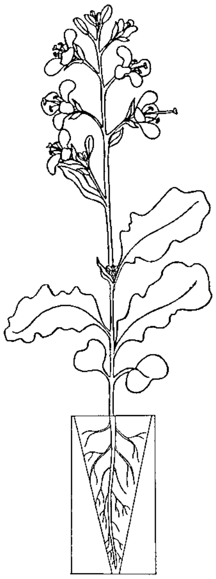
Dr. Musgrave reports that in no case was there a statistically significant difference between microgravity and the 1 g environment of Earth. This bodes well for future experiments and sets the stage for an upcoming space shuttle flight. Space Shuttle Columbia flight STS-87 provides the next "real time" classroom opportunity, with lift-off currently scheduled for November 19, 1997.



AstroPlants Student Plant Growth Chamber, (PGC)

In this collaborative experiment between the United States and Ukraine (CUE), teachers and students in both countries will be able to grow and pollinate AstroPlants to compare the success rates of fertilization and the development of embryos under Earth's gravity with how pollination and post-fertilization events proceed in the microgravity of space (see Winter 1996 *Notes*).

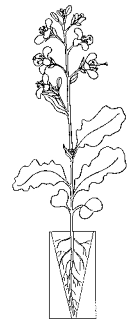
Comparisons of student and scientist data will be made on the height of the plants at Day 14, the number of days to first open flower and the number of seeds produced in each pod. See the details on page 7 to get your classroom involved!



Challenging All Students!

Can anyone surpass the accomplishments of the Gregor Mendel Seed Company? If it took approximately 8 or 9 generations to go from the 20 cm tall basic Fast Plants to the 10 cm AstroPlants, why have the students in Augusta, Wisconsin been able to reverse the procedure (AstroPlants to 50 cm plants) in fewer generations?

When the real time CUE experiment begins next fall, which classroom is going to produce the most seeds on their eight experimental AstroPlants growing in the model Plant Growth Chambers? Which set of classroom data will most completely resemble the data coming back from the Shuttle plants? Would anyone like to venture what the next "small step" or "giant leap" will be in the space odyssey of the AstroPlants?



Upcoming Workshops and Exhibits

NABT Convention – October 8-11, Minneapolis

The Wisconsin Fast Plants Program will have a booth featuring the CUE-TSIPS project at the convention of the National Association of Biology Teachers in Minneapolis. Stop by and check out what CUE is all about!

Use a "dissection strip"! Pollinate with a beestick! Tumble in space with a gravitropism chamber! Make a Fast Plants bookmark!

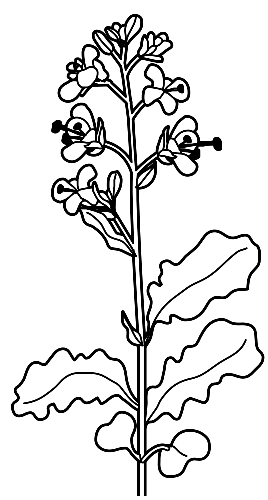
A CUE-TSIPS workshop is not currently scheduled, but may be offered. Check the convention schedule for a listing of time and place. For information on attending the convention, contact the NABT staff at 800-406-0775 or NABTer@aol.com.

Wisconsin Fast Plants and CUE-TSIPS – October 24-25, Madison

The WFP staff is offering a two day workshop open to K-college teachers. This crash course in Fast Plants will first cover the in's and out's of the CUE-TSIPS project via the basics of the life spiral – germination, growth, development and reproductive indicators – including the life cycle activities and supplemental experiments in plant orientation and guidance.

These activities will be followed by a look at inheritance and the effects of the environment on Fast Plants. Bottle Biology will also be incorporated into various parts of the workshop.

The cost of the workshop is $100. For more information, contact the Wisconsin Fast Plants Program office by phone at 800-462-7417 or by email at wfp@fastplants.cals.wisc.edu. You can also visit the WFP World Wide Web site at http://fastplants.cals.wisc.edu for updates on this and other workshops.



CUE-TSIPS: Launch Your Students into Space!

The Collaborative Ukrainian Experiment education project, "Teachers and Students Investigating Plants in Space", or "CUE-TSIPS" offers teachers and students a chance to become involved in a real-time space experiment. ***Get involved!***

You can request a free copy of the teacher guide (*Teachers and Students Investigating Plants in Space*) from the NASA Educator Resource Center for your region (see page 8).

Students conducting the experiment will grow a life cycle of AstroPlants under a fluorescent light bank in the classroom, measure and record data, pollinate the plants, and track the development of the embryos. Class data can be entered into a database on the WFP WWW site. These data will be compiled for comparison with data from other classrooms in the U.S. and Ukraine and later compared with data from CUE scientists Drs. Mary Musgrave (Louisiana State University) and Antonina Popova (Ukraine).

Training workshops span the spring, summer and fall of 1997 in locations across the country. ***You do not need to attend a training workshop to participate in the CUE-TSIPS project.*** See page 6 for information on a workshop being offered by WFP on October 24-25 in Madison.

The CUE-TSIPS Critical Info

- Launch Date: Currently scheduled for November 19, 1997.
- Age of Plants at Launch: 12 days old.
- "Real Time" Planting Date: November 7 – This date will give you just enough time to complete the life cycle before the December holiday break.
- Contingency Plan: Even if the launch date changes, stay with the November 7 planting date so that you can share data and experiences with WFP and other classrooms on the Internet.
- Critical Teacher Guide Pages: Mission Calendar (pages 29-31), AstroPlants Growth Data Sheets (pages 41-42), Floral Clock Data Sheets (pages 51-52)
- Submit Data to WFP: Class data can be submitted to WFP via the Internet. To enter your class data, go to:

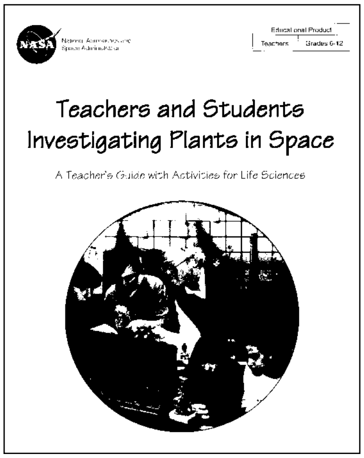
  http://fastplants.cals.wisc.edu/cue/cuedata.html

  Three data points will be evaluated to provide particularly relevant information about growth, development and reproductive indicators for the ground-based controls:

  1) average plant height at Day 14
  2) average number of days from sowing to first open flower
  3) average number of seeds produced in each pod
- "Real Time" Networking: Access Excellence and WFP have established an on-line forum for discussions during the CUE-TSIPS project. To learn how to register with AE and join in, go to:

  http://fastplants.cals.wisc.edu/cue/ae.html
- Project Evaluation: A project evaluation form for CUE-TSIPS is available on-line. To submit your evaluation, go to:

  http://ednet.gsfc.nasa.gov/edcats/partnership/fastplants_followup.html



How to get the teacher guide

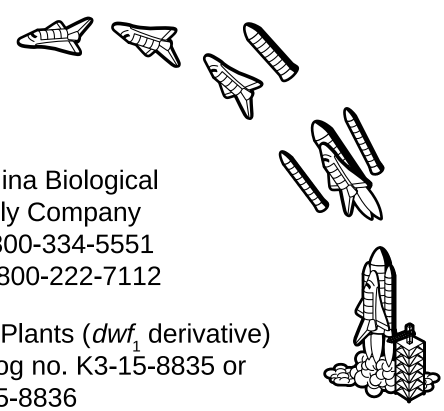
If you wish to be involved in the CUE-TSIPS project, you can request the instructional guide "Teachers and Students Investigating Plants in Space" (NASA publication number EG-1997-02-113-HQ) by contacting the Educator Resource Center for your state, using the list below.

IF YOU LIVE IN:			***CONTACT:***
Alaska Arizona California Hawaii Idaho Montana	Nevada Oregon Washington Wyoming Utah		NASA Ames Research Center Phone: (415) 604-3574
Connecticut Delaware District of Columbia Maine	Maryland Massachusetts New Jersey New York	Pennsylvania Rhode Island Vermont	NASA Goddard Space Flight Center Phone: (301) 286-8570
Colorado Kansas Nebraska	New Mexico North Dakota Oklahoma	South Dakota Texas	NASA Johnson Space Center Phone: (281) 483-8696
Florida Georgia	Puerto Rico Virgin Islands		NASA Kennedy Space Center Phone: (407) 867-4090
Kentucky North Carolina	South Carolina Virginia	West Virginia	Virginia Air and Space Center Phone: (757) 727-0900 x 757
Illinois Indiana	Michigan Minnesota	Ohio Wisconsin	NASA Lewis Research Center Phone: (216) 433-2017
Alabama Arkansas	Iowa Louisiana	Missouri Tennessee	U.S. Space and Rocket Center Phone: (205) 544-5812
Mississippi			NASA John C. Stennis Space Center Phone: (601) 688-3338

Relevant Internet sites:

- **CUE:**
  http://fastplants.cals.wisc.edu/cue/cue.html
  http://atlas.ksc.nasa.gov/education/general/cue.html
- **NASA Home Page:**
  http://www.nasa.gov
- **NASA Spacelink:**
  http://spacelink.msfc.nasa.gov
- **STS-87:**
  http://www.osf.hq.nasa.gov/shuttle/sts87

How to get AstroPlants seeds:



Contact: Carolina Biological Supply Company
tel: 800-334-5551
fax: 800-222-7112

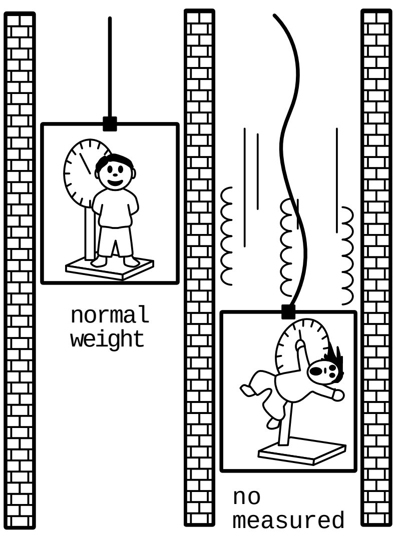
Stock: AstroPlants (*dwf*$_1$ derivative)
catalog no. K3-15-8835 or K3-15-8836

Microgravity

Excerpted from the NASA teacher guide, *Teachers and Students Investigating Plants in Space*. Contributed in part by Greg L. Vogt (Crew Educational Affairs Liaison, NASA Johnson Space Center).

Gravity is an attractive force that is a fundamental property of all matter. Whether an object is a planet, a feather or a person, each exerts a gravitational force on all other objects around it. Physicists identify gravity as one of the four types of forces in the universe (the others are strong and weak nuclear forces and electromagnetic force).

The strength of the attraction between two objects is directly proportional to the product of the masses of those objects and inversely proportional to the square of the distance between the centers of mass of those objects: in other words, the larger the objects the stronger the attraction between them and the greater the distance between the objects the weaker the attraction. When measured at the surface of the Earth, the acceleration of an object acted upon only by Earth's gravity is commonly referred to as "1 g" or "unit gravity." This acceleration is approximately 9.8 meters per second squared (m/s^2).

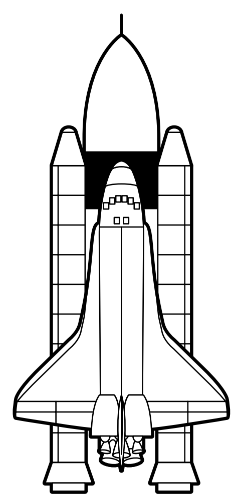


The term microgravity can be interpreted in a number of ways, depending upon context. The prefix "micro-" (μ) is derived from the original Greek "mikros," meaning "small." By this definition, a microgravity environment is one that will impart to an object a net acceleration that is small compared with that produced by the Earth at its surface. Another common usage of micro- is found in quantitative measurement, such as the metric system, where micro- means one part in a million.

On Earth, gravitational force is important in providing orientation and guidance to many forms of life including plants. For example, plants orient themselves with gravity so that shoots grow up and roots grow down and water and nutrients are transported through the plants against the pull of gravity.

Although gravity is a force that is always with us, its effects can be greatly reduced by the simple act of falling. NASA uses the term "microgravity" to refer to the condition that is produced by a "free fall."

NASA uses airplanes, drop towers and small sounding rockets to create a microgravity environment for experimental purposes. In each facility, an experimental payload is put into free fall that lasts from a few seconds to several minutes. Eventually, free fall ends because the object will impact on the Earth's surface.



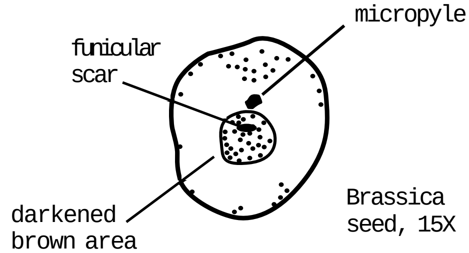
When scientists want to conduct experiments in microgravity for longer durations – days, weeks, months or even years – it is necessary to travel into space and orbit Earth. Having more time available for experiments means that slower processes and more subtle effects can be investigated.

Today, the Space Shuttle and special satellites are the space facilities that provide opportunities for these microgravity experiments. The International Space Station will soon be an important additional means of accomplishing such investigations.

"Launching the Seed"

Introduction

If your students have looked closely at brassica seeds, hydrated and dissected them, they may have found that the tip of the embryonic root points down toward the micropyle, near a darkened circular area on the seed coat associated with the attachment of the seed to the maternal ovary by way of the funiculus. Follow the steps below to begin to explore the interaction of germination and orientation.



Question: For a brassica or other seed, which way is down? Or up?

Sample Hypothesis: The dark spot near the micropyle is down – brown is down.

Sample Null Hypothesis: Brown is up.

Design:

- Germinate seeds oriented in different directions. Observe and record initial and later direction of root emergence from seed. Alter orientation of seedlings, predict, observe and record responses.
- Observations are recorded on the "Launching the Seed Student Sketch Sheet," (page 12).
- ***Design Tip:*** You may want to begin this activity on a Monday, so that your germination will occur during the week when students can make observations. Alternatively, students may set it up and observe it at home.

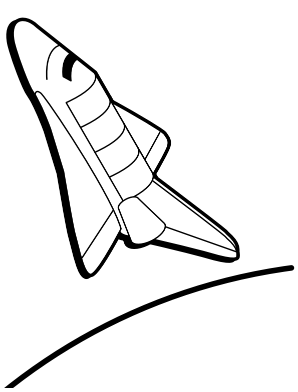
Time Frame

Students will be able to construct their seed germinator and place their seeds within one 50 minute class period. This activity is designed for the student to observe their germinators over a two to three day period. Data are collected as drawings and a written discussion. Time for observations should be five to ten minutes on each of three consecutive days.

Learning Objectives

In participating in this activity students will:

- determine whether their understanding of seed anatomy is correct and their hypothesis regarding seed orientation is verified, namely that the micropyle is the down orientation in brassica seeds; and
- understand that plant roots reorient in the direction of their growth to conform with the direction of the gravitational force.



Materials

- two soda bottle caps (film can lids will also work)
- kitchen plastic wrap
- paper toweling
- four brassica or other similar-sized seeds (lettuce, turnip or alfalfa)
- forceps for handling seed
- hand lens
- elastic band

Procedure

1. Cut two layers of paper towel into circles that will fit into the bottom of a soda bottle cap.

2. Place the towel in the cap and moisten it with water. Pour off any excess water.

3. Orient the four seeds in north-south-east-west positions on the moist towel surface, making sure that the brown micropyle area (spot) is pointing toward the center of the cap (Figure 1).

4. Make a mark on the bottle cap that indicates the direction of north, or up.

5. Cover the open cap with plastic wrap and secure the wrap with an elastic band. Trim off excess wrap with scissors.

6. Position the "bottle cap seed germinator" so the seeds are in a vertical orientation by standing it in a second bottle cap (Figure 2).

7. Make a drawing of the seeds in the bottle cap germinator, including the orientation of the brown micropylar area toward the center of the circle. Use the "Circle 1" on the Launching the Seed Student Sketch Sheet.

8. If students carry their bottle cap seed germinator home with them, they can **observe it every few hours**. Be sure to keep it in the vertical position with the proper north-south-east-west orientation.

9. When the roots begin to emerge, record the direction of the emerging root from each seed with a second drawing on the Sketch Sheet (Circle 2). You may wish to use a hand lens.

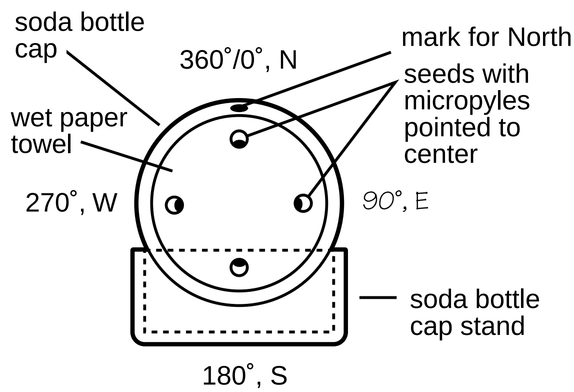


Figure 1: Front view of bottle cap seed germinator.

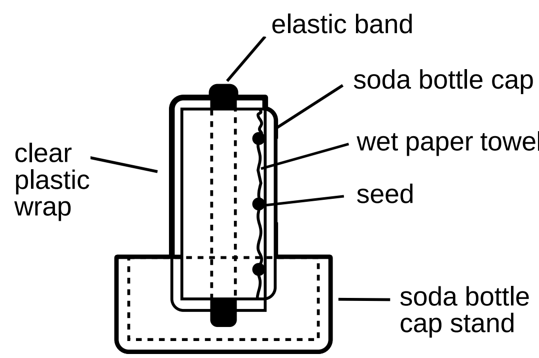


Figure 2: Side view of bottle cap seed germinator.

10. Continue to observe the germinating seeds being sure that the paper towel is kept moist. Note the appearance of the fine, fuzzy root hairs and the extension of the hypocotyl.

11. **After 24 to 48 hours**, make a third drawing depicting the direction of the roots and hypocotyl and illustrating the root hairs, cotyledons and seed coat (Circle 3).

12. Then reorient your bottle cap seed germinator in some way that will give you more information on seed orientation. Make another drawing that predicts how the seedlings will look after 12 or 24 hours in this new orientation (Circle 4). Observe them from time to time – do you notice anything happening?

14. **Twelve or 24 hours** after reorientation, draw the seedlings on the Sketch Sheet (Circle 5). Has anything changed? Compare the outcome of the orientation with what you predicted in your last drawing.

15. Have students write about what they have learned on the Sketch Sheet.

Concluding Activities and Questions

In this activity students will have observed the effects of the Earth's gravity in reorienting the direction of roots in the direction of the gravitational force. They will also have observed that shoots orient against the direction of the gravitational force, bending and growing upward. This should raise a discussion around the questions:

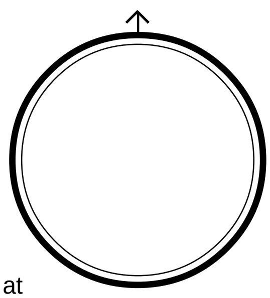
- In microgravity which direction will roots and shoots grow?

- Is there a guiding force for root growth in the absence of gravity? Could you generate a hypothesis and experiment to carry this question farther? ***Hint:*** What would happen if you ran this experiment on a centrifuge?

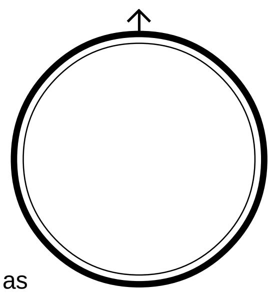
- What might be the possible influence(s) of light in this experiment?

'Launching the Seed'
Student Sketch Sheet

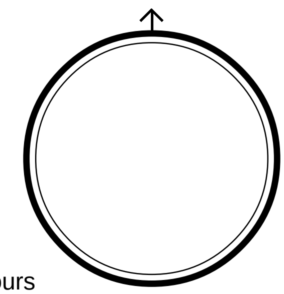
Circle 1: Sketch and label your bottle cap seed germinator at time of placement of seeds.



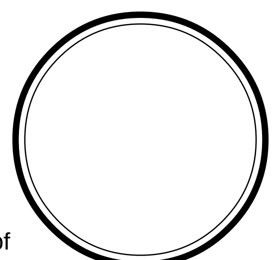
Circle 2: Sketch and label your bottle cap seed germinator as the roots emerge from the seeds.



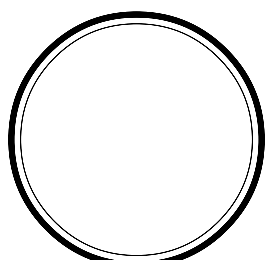
Circle 3: Sketch and label your bottle cap seed germinator 24 to 48 hours after placement of seed.



Circle 4: Sketch and label your bottle cap seed germinator with your prediction of the effects of reorientation on your seedlings.



Circle 5: Sketch and label your bottle cap seed germinator 12 or 24 hours after reorientation to compare with sketch in Circle 4.



Write about what you have learned about germination and orientation.

Tech Section:

Fast Plants Lighting Enters the 21st Century

Traditional Fast Plants Lighting

Appropriate lighting is perhaps the most critical component of a plants' growing environment. If you are using the standard four-foot Fast Plants light bank, you can use either eight 40 watt cool white or six 32 watt high-efficiency bulbs to produce "ideal lighting" for Fast Plants. Do not put the energy saving bulbs in the older light fixtures when growing Fast Plants. With the lights on 24 hours/day, the mismatch of bulb and fixture will soon result in a burned out fixture. Fluorescent circle lights also provide adequate light for Fast Plants (see page 14)

Introducing the "Troffer"

The "Troffer," with either four or six bulbs, is very energy efficient and appears to be ideal for growing Fast Plants on a large scale. These lights are designed for use in the ceilings of doctors' offices and hospitals where high light intensity is needed. They are not yet commercially available through local hardware stores or scientific product distributors and must be ordered through an electrical supply company.

The four bulb troffer provides adequate light for Fast Plants, but the six bulb troffer is "ideal." It emits more irradiance around the edge of the fixture than the four bulb and should be used if you need the entire space under the light for growing your Fast Plants.

How to order:

These fixtures are not available through hardware stores and must be purchased from an electrical supply company.

If you can not find a store that carries Lithonia Lighting Products, call Lithonia at 770-922-9000 to find the nearest distributor.

The troffer fixtures are referred to in the electrical industry as:

Static Grid Troffer GT 2' X 4'
Four T8 32-watt bulbs
Lithonia Unit # **2GT432A1201/4GEB** 120V

OR

Static Grid Troffer GT 2' X 4'
Six T8 32-watt lamps
Lithonia Unit # **2SPG632LFLS1202/3GEB** 120V

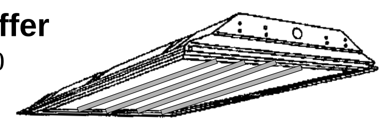
The six lamp troffer normally must be special ordered and will take about six weeks for delivery.

Both troffers come with a diffuser screen that must be removed for growing purposes. Troffers can be ordered without the screen, which saves $12-$15.

Note: We recommend having a qualified electrician wire the fixture.

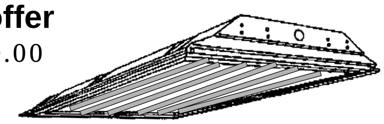
Lithonia 4 Bulb Troffer

Price: $50.00 - $65.00



Lithonia 6 Bulb Troffer

Price: $100.00 - $120.00



The bulbs or "lamps" are 32-watt and are referred to as a 32-watt T8. The specifications are:

Sylvania Octron
4100K F032/741

The troffer fixtures do not come with a power cord and plug. Other necessary materials for setting up the troffer fixtures are:

- 3' power supply cord (one per troffer), two conductor with ground (3 wires - black, white, and green)
- twist-on wire connectors (two per troffer)
- Romex Connector (one per troffer). This type of connector is normally only available through an electrical supply company.

Photosynthetic Irradiance

Photosynthetic photon flux, PPF, was measured using a LI-COR photometer unit (http://licor.com) on a 120 X 60 cm grid at 10 cm intervals, 10 cm below the bulbs. Numbers represent readings of PPF in $\mu mol.m^{-2}.s^{-1}$.

PPF between 100 and 199 $\mu mol.m^{-2}.s^{-1}$ is adequate for Fast Plants. A PPF of 200 $\mu mol.m^{-2}.s^{-1}$ or greater is ideal for Fast Plants.

☐ indicates less than adequate light for WFP (see WFP ID, "Seeing the Light").

Lithonia 4 Bulb Troffer

71	109	119	127	135	131	127	128	127	131	113	76
114	183	197	209	208	208	207	208	201	198	169	121
115	174	197	205	208	208	207	206	204	199	177	130
101	179	203	210	214	214	213	212	208	202	178	124
100	142	173	183	180	184	183	184	185	175	155	118
54	92	97	102	113	111	110	110	105	105	88	65

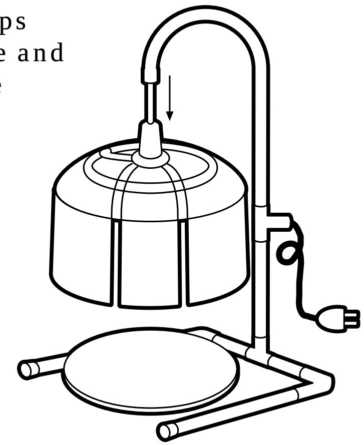
Lithonia 6 Bulb Troffer

102	139	164	175	179	191	182	195	175	161	144	111
129	222	258	272	280	290	291	294	296	295	276	189
126	225	261	275	278	286	292	291	286	278	260	192
132	237	267	286	291	292	293	291	289	278	254	182
135	247	279	285	295	296	300	193	289	273	251	181
104	156	208	208	184	193	187	193	175	167	148	109

Six 40 watt 4-foot bulbs (standard WFP light bank)

46	73	84	88	89	89	89	90	86	81	64	41
84	122	133	134	135	135	135	135	130	128	115	71
87	136	154	158	160	160	160	160	158	151	131	79
84	135	154	160	162	163	164	163	161	154	132	80
75	119	134	138	139	134	142	139	136	133	116	71
47	71	86	90	90	90	87	86	86	80	67	39

Circle Lights



Fluorescent "circle" lamps can be suspended above and will adequately irradiate the plants growing within a circle of 30 cm diameter (12 inches). The Wisconsin Fast Plants Program has had the most successful growth under 30 or 39 watt circular or "folded" circular bulbs.

Reflectors made from aluminum foil or reflective mylar (available from fabric or stationery stores) greatly increase the irradiance reaching the plants, particularly those around the edges of the lamps, and contribute to uniform lighting.

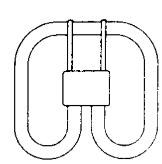
You can make your own circle light! Purchase a circular or folded circular bulb and a socket with an electrical cord. Cut a hole in the center of an aluminum pizza pan, insert the socket through the hole and attach the bulb.

Suspend the circle light over the plants, making sure that the cord is secure and will not slip. Use reflective curtains of aluminum foil.

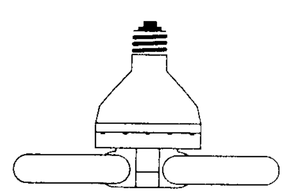
Tips: Keep your Fast Plants under constant 24 hour light. The growing tips of the plants should be kept 5-10 cm from the bulbs.

New Bulbs

GE Soft White Electric Fluorescent Adapter with Bulb, 39 watts) and the 30 watt circular bulb (made by various manufacturers) can be purchased at local home supply stores.



folded circular bulb



bulb with adapter

"Pressing Matters"

Pressing and preserving plants and flowers is fun and informative! Pressed specimens are a critical part of plant classification and are kept in herbariums and botany gardens around the world.

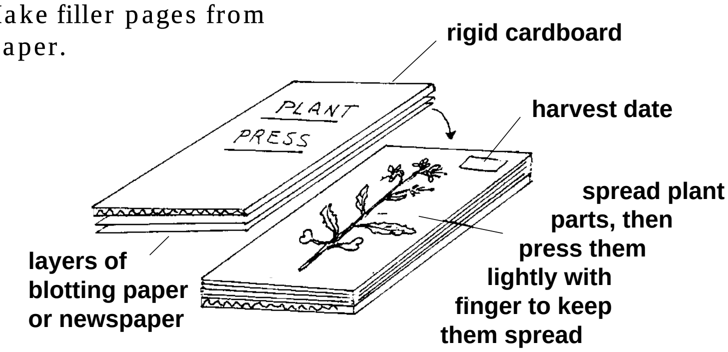
Prepare the plant presses

Before plants flower, day 18, students can make a plant press. The outside layers can be made of heavy cardboard. Make filler pages from pages of telephone books, newspaper, or blotting paper.

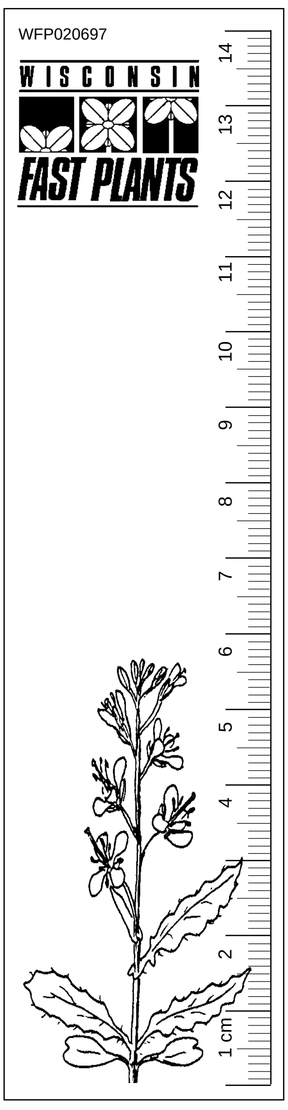
Harvest and press plants

1. Carefully harvest plants by snipping them off at soil level. Transfer plants to the press.

2. Carefully spread the leaves, flowers and seed pods, pressing them firmly with a finger to flatten them against the filler page. Then cover with additional filler pages.



3. Place the second cardboard layer on top and secure the whole press with large rubber bands, clips or under a stack of books. Let the plants dry for at least one week.



Laminate your pressed plants

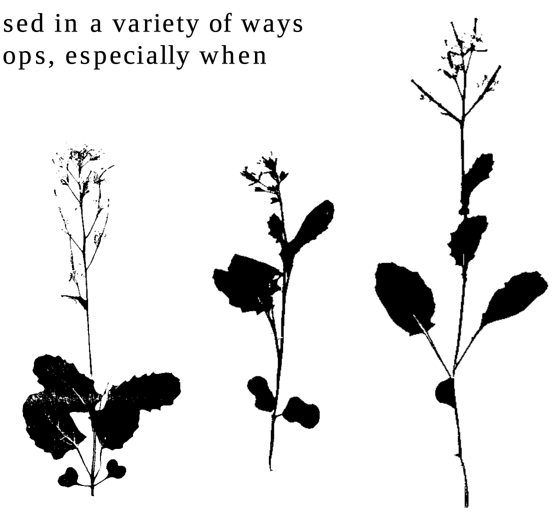
Pressed plant specimens can be preserved by mounting them on a Fast Plants bookmark (at left) and covering them with clear laminating sheets. Use a small piece of adhesive tape can help to hold the plant in place. Dry plants are fragile, so care should be taken not to break off leaves, flowers and/or seed pods.

"Do it yourself" laminating sheets (e.g., Cleer-Adheer from C-Line Products, Inc.) can be purchased at local office or art supply stores. These sheets can be cut to size to fit your bookmarks. Cover front and back to enclose the mounted plant.

Use your laminated plants

Pressed and laminated plants can be used in a variety of ways in the classroom or in teaching workshops, especially when time or resources are not available to produce live plants. The mounted plants are easily xeroxed; sets with plants at different ages can be used to explore the life cycle.

Measurements can also be taken from laminated plants or their xeroxes. Data can be collected on a pressed population!



New Email Address for Fast Plants

WFP has changed its email address! Mail sent to the older address is forwarded, but the staff can now be reached at:

wfp@fastplants.cals.wisc.edu

As always, you can check out Fast Plants on the Internet by visiting our Web site at:

http://fastplants.cals.wisc.edu

At this site you will find:

- **WFP Flashes**
  Be sure to check in with the Fast Plants Program, both what the staff has been up to lately and what is coming up.
- **WFP FAQ (Frequently Asked Question) List**
  Do you have questions about Fast Plants? We have compiled a listing of some of the most frequently asked questions into a FAQ list, and present them with the answers to help you.
- **Programs and Projects**
  Check here for news and information on Fast Plants educational projects and related programs.
- **Field Guide to Fast Plants**
  Everything you want to know about Fast Plants and more!

In this issue:

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