Gravitropism: Tumbling in Space

Introduction

This activity utilizes the "**film can gravitropism chamber**" in one of many experiments that can be designed to answer a large number of questions that students may ask relating to the question: How do plants 'know' which way to grow?

Begin by making the assumption that on Earth, in the absence of light, plants sense and respond (orient) to the gravitational force of 1 g (unit gravity).

Question: How responsive is the germinating seedling to Earth's gravity?

Sample Hypothesis: The Fast Plants seedling hypocotyl will respond rapidly and continuously, exhibiting negative gravitropism at least over a 72 hour period.

Design

- Seeds are germinated in the dark over several days and are observed and measured for their directions of growth. At specified intervals of time, orientation is altered progressively by 90˚ of rotation through 360˚ of rotation.
- Prior to reorientation, the response of the seedlings is predicted in a drawing.
- At each orientation, growth response is recorded on the Gravitropism Data Sheet.
- The experiment is designed so that it can be run either at home or in class.

Time Frame

Construction of and placing seed within the film can gravitropism chamber will require one 50 minute class period. Observation and data taking will require time on the day of chamber construction and the two following days, approximately 15 minutes per day at specified intervals.

Learning Objectives

In participating in this activity students will:

- learn that seedling hypocotyls (shoots) orient strongly in the direction opposite to the direction of the force of gravity;
- understand that the tropic response in seedlings is rapid and occurs in the absence of light;
- construct a simple piece of experimental equipment from low-cost materials; and
- develop spatial-temporal skills by predicting what seedling orientations will be in each of the four positions of the film can gravitropism chamber at each reorientation.

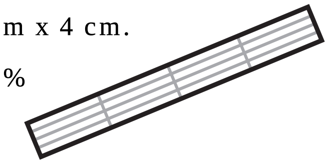
Materials *(per group of four students)*

- 35 mm black film can with lid
- two extra film can lids
- clear double stick tape or double stick mounting tape
- white masking or lab tape, 2 cm wide
- four grid strips, 0.5 cm x 4 cm pieces cut from millimeter square graph paper photocopied onto overhead transparencies
- four wick strips, 1 cm x 4.5 cm strips of soft paper toweling
- one floral foam disc, 28 mm diameter, 2 to 4 mm thick
- four Fast Plants seeds
- water bottle
- forceps to handle seed
- ultrafine permanent black marker

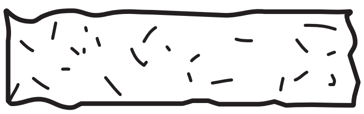
Department of Plant Pathology, 1630 Linden Drive, Madison, WI 53706 1-800-462-7417 wfp@fastplants.cals.wisc.edu

Preparation of Germination Strip

- *Making grid strips:*
  - Photocopy millimeter square graph paper onto an overhead transparency sheet.
  - Cut the sheet along the lines to make strips with the dimensions 0.5 cm x 4 cm.
  - Grid strips can be reused after rinsing, soaking for 20 minutes in a 20% bleach solution, then rinsing again and drying on paper toweling.

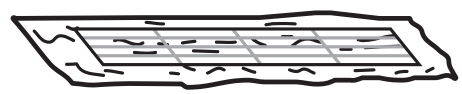


- *Making wick strips:*



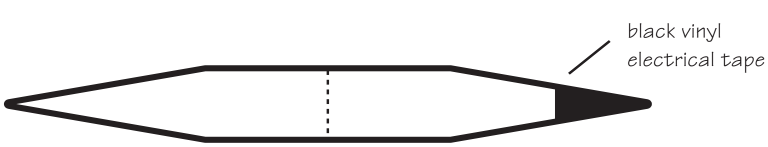
  - Fold a square sheet of kitchen paper toweling to form an eight layered rectangle.
  - With scissors, trim end and folds to make a rectangle with the dimensions 4.5 cm x 10 to 12 cm.
  - Cut wick strips from the rectangle by cutting 1 cm strips.

- *Making germination strips:*
  - Hold a wick strip with a grid strip aligned on top of it. Moisten the wick strip.
  - As the wick strip becomes moist through capillary action, the grid strip will adhere to it through the adhesive forces of the water. Together the wick and grid strip make a germination strip.

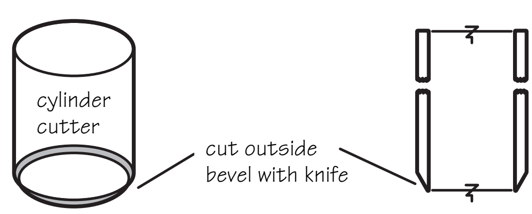


  - The wet germination strip will adhere to the inner wall of the film can gravitropism chamber.

- *Making plastic seed forceps:*
  - Cut a strip 1 cm x 10 cm from a piece of the flat side of a heavy plastic food or detergent bottle.
  - Bend the strip in half and crimp the fold lightly between your thumb and forefinger.
  - With scissors, trim edges to points of desired taper and precise alignment.
  - Place a triangle of electrical tape on the inner surface of one of the forceps tips by taping on a square and trimming of the excess tape with scissors. The tape will cushion the seeds and prevent them from slipping from the forceps.

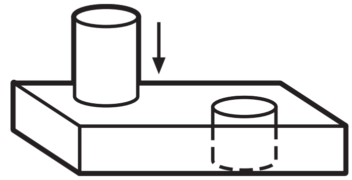


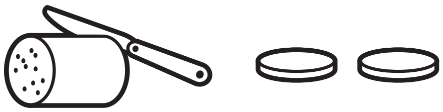
- *Making floral foam discs:*
  - Prepare discs by cutting foam cylinders with a Fuji® brand "film can foam cylinder cutter" created by cutting off the bottom of a Fuji® film can and beveling the outside edge with a knife.



It is important to use clear Fuji® film cans for this step because the foam cylinders and foam discs will have a diameter of 28 mm required to fit inside the tropism chamber.

- Cut foam cylinders by carefully pressing the cylinder cutter completely through a dry floral foam block.





- With a flat knife slice discs of foam 2 to 4 mm thick from the cylinders.

Procedure

1. Each student or group of students should construct a **film can gravitropism chamber**.

   - On each extra film can lid place a 3 cm strip of double stick tape and then attach the lids to the outside wall of the film can so that each lid is opposite the other.

   - Mark the film can using an ultrafine tipped permanent marking pen to draw arrows on the film can lid and one of the mounted lids as in Figure 1 to indicate "FRONT".

   - With the front facing you, stick a white label on the right side of the chamber and draw a compass on the label, marked with angles of 0˚/360˚, 90˚, 180˚ and 270˚, corresponding to north, south, east and west (Figure 2).

   - As indicated in the right side view drawing of Figure 2, put in arrows indicating a counterclockwise direction or rotation.

2. Place the floral foam disc in the bottom of the film can.

3. With a water bottle, add enough water to saturate the floral foam and just a little more free water in the bottom.

4. Dip the end of a germination strip into the bottom of the can, touching the water until it wicks up some of the free water.

   - Align the germination strip vertically inside the film can, with grid strip against the inner wall and the wick strip overlapping it and adhering to the wall.

   - You may tilt the film can to encourage the free water to ascend the wick strip and speed the adhesion of the wick to the wall.

5. Align the germination strip with the front orientation of the chamber. At this stage you may let the strip extend above the rim of the film can chamber.

Figure 1: Front view of film can gravitropism chamber.

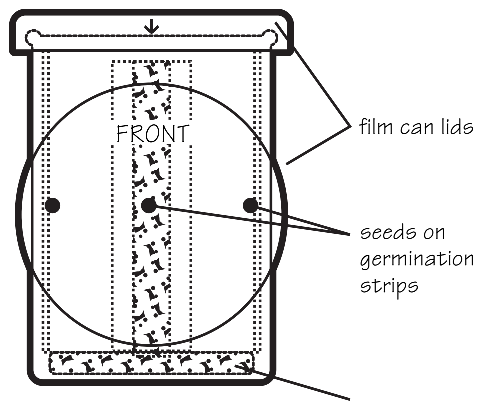
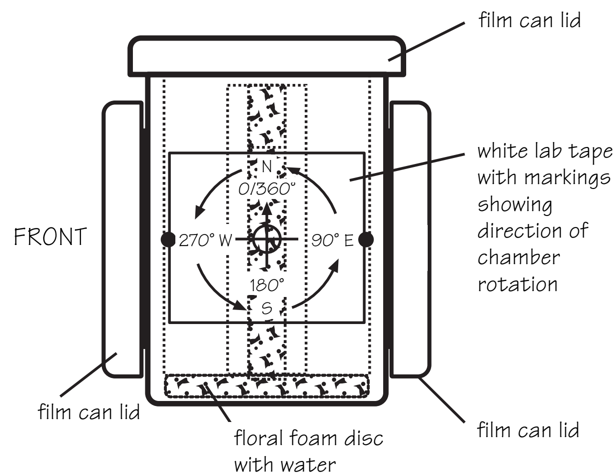


Figure 2: Side view of film can gravitropism chamber.



6. Repeat the procedure with the other germination strips, aligning them to create four strips opposite each other aligned at 90 degree angles, as illustrated.

7. Now remove one strip pair from the chamber and with your finger or using seed forceps to pick up one seed, place it about 2 cm down the strip. The seed will adhere to the wet paper towel.

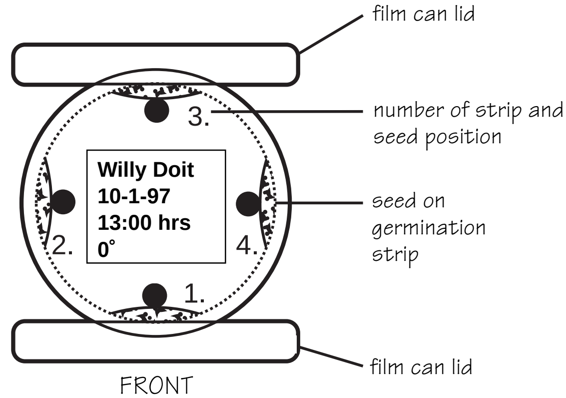
8. With a forceps or a pencil point align the seed so the micropyle points down, see WFPID *Getting Aquainted With a Seed*).

9. Replace the strip with seed to its original position in the can, but this time push the germination strip down so that the bottom of the wick strip connects with the wet floral foam disc and the top of the strip is below the rim of the film can chamber. *It is critical that the top is below the rim, or when the chamber is closed, the moisture from inside will "wick" out of the can.*

10. Repeat steps 8 to 10 until all four seeds are on the four wick strips in the chamber.

11. Make a final check on the amount of water in the bottom of the chamber.

Figure 3: Film can gravitropism chamber, view from above.



- If there is excess free water, gently tip the chamber and let the extra water drip out, making sure not to wash off the seeds.

12. Gently place the film can lid on, sealing the chamber. Be sure that the arrow on the lid is aligned with the arrow on the front cap of the chamber.

    - As indicated in Figure 3, each strip has a numbered position, 1 to 4: 1 is front, 3 is back, 2 is left and 4 is right.

13. Put a white tape label on the top lid of the film can with the following information recorded: your name, the date (e.g., 10-1-97), the time on a 24 hour clock (e.g., 13:00 hours), and the symbol "0˚" indicating the initial orientation of the chamber (upright). Add the information from the chamber label into the first three columns on the Gravitropism Data Sheet. **Germination in the absence of light has begun at hour zero.**

14. Place the chamber in the upright, 0˚/360˚ position, where a relatively uniform temperature between 22˚C and 30˚C can be maintained. Under your light bank is ideal.

15. **Be prepared to observe your chambers every 12 to 24 hours**, noting any elongation of the seedling hypocotyls.

    - When the seed and seedlings are observed, keep the lid open only for as long as necessary.

    - If a seedling has fallen off of its wick strip, it may be placed back gently, picking it up with a forceps. If a seedling's root is growing off of the wick strip, it can be gently pressed to the wick where its root hairs will attach firmly. If it looks like more water is needed, add a few drops to the foam disc.

16. Sometime **between 24 and 48 hours**, depending on the temperature, the seedling hypocotyls will be between 1 cm and 2 cm long. Make a drawing of the vertical seedling on each strip in the appropriate box in the first row of the Gravitropism Data Sheet. Record the date, time (on a 24 hour clock) and total cumulative hours from hour zero.

17. **At this time rotate the chamber by 90˚**. As the chamber is rotated, think about the possible outcome of reorienting the four seedlings.

- What will the seedling on each strip look like after 12 to 24 hours? Students should make a drawing on the Gravitropism Data Sheet of how they predict each seedling will appear.

18. Record the date, time and total cumulative hours of your first 90˚ rotation on the Gravitropism Data Sheet, and each rotation thereafter.

19. **After 3 to 12 hours or 24 hours** (3 to 6 is best), observe the chamber. Mark the time and date on the Data Sheet and next to the predicted sketch, make a quick but accurate sketch of how the plant on each strip appears.

- The chamber should then be rotated another 90˚ to the 180˚ position. A predictive drawing should be made on the Data Sheet and after 3 to 12 hours, repeat the cycle of observation, drawing and rotation. Be sure to record the date, time and total cumulative hours.

20. Continue rotating, observing and drawing until the chambers have completed 360˚ of rotation. Would students like to try to keep it going? Have them try it!

21. When the rotations have been finished carefully remove each strip with its seedling attached and make a final drawing.

- Stretch out the seedling to straighten it, then accurately record the length of the hypocotyl from the hypocotyl from the cotyledon to the root hypocotyl junction above where the root hairs first appear.

- On the Gravitropism Data Sheet, record the length of the hypocotyl in millimeters.

Concluding Activities and Questions

In this activity students will have observed the effects of gravity in orienting the growth of seedlings. Have students consider the following:

- Discuss the outcome of the experiment relative to the original hypothesis. Was the hypothesis verified? How strong is your evidence? Were you able to successfully predict how the seedlings would respond to successive reorientation of the chamber?

- What is the average length of the hypocotyls in your chamber after X hours of germinating in the dark? You fill in the X!

- How long is it possible for a hypocotyl to grow in the dark?

- Is there a limit to how long it would grow? If there is, what is it?

- When it is elongating, how is the hypocotyl actually growing longer? By what mechanism?

- Is there a limit to how much bending a hypocotyl can undergo?

- What would the orientation behavior of the seedlings be like in microgravity?

- Try using this film can gravitropism chamber with 3-4 day old cut Fast Plant seedlings similar to those used in the WFPID's *Hypocotyl Hypothesis* and *Crucifer Cross*.

Gravitropism Data Sheet

Student Name 1 ____________________
Student Name 2 ____________________
Student Name 3 ____________________
Student Name 4 ____________________

Environment
Temperature Range: __________ ˚C
Average Daily Temperature of Growing Environment: __________ ˚C

Date	Time (24 hr clock)	Total Hours	Hours from Last Rotation	Rotation Angle	Germination Strip Position Number 1		2		3		4	
					predicted	observed	predicted	observed	predicted	observed	predicted	observed
			0	0	X							
				90								
				180								
				270								
				360								
length of hypocotyl after ______ hours:					______ mm		______ mm		______ mm		______ mm	