Tropism Testing

Lesson 4

Lesson Reference: National Space Biomedical Research Institute's Plants in Space Teacher's Guide at http://www.bioedonline.org/lessons-and-more/teacher-guides/plants-in-space/ and NASA's lesson on Gravitropism at https://www.nasa.gov/offices/education/programs/national/summer/education_resources/lifescience_grades4-6/LS_how-do-plants-know.html

This lesson involves the growing of plants so the time required spans over several days.

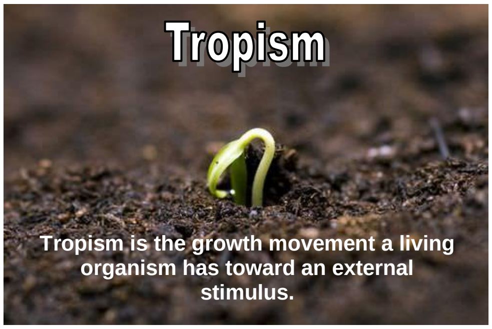
Objectives:

- Students will explore the effects of gravity on plant growth.
- Students will apply the principles of experimental design, data collection, analysis, and presentation.
- Students will gain experience in measurement.
- Students will collaborate in teams to set up and conduct an experiment to demonstrate the effects of gravity on plant growth.
- Students will gather data by observing what happens to the growth of the seeds in the team-designed experiment.
- Students will use data to explain the changes observed in the seeds.
- Students will develop a conclusion based upon the results of this simulation.

National Standards:

Science

- Unifying Concepts and Processes
    - Systems, order, and organization
    - Evidence, models, and explanation
    - Change, constancy, and measurement
    - Form and function
- Content Standard A: Science as Inquiry
    - Abilities necessary to do scientific inquiry
    - Understandings about scientific inquiry
- Content Standard B: Physical Science
    - Motion and forces
- Content Standard C: Life Science
    - Structure and function in living systems
    - Regulation and behavior
    - Ecosystems
    - Diversity of organisms
- Content Standard E: Science and Technology
    - Abilities of technological design
- Content Standard G: History and Nature of Science
    - Science as a human endeavor



Source: https://flexbooks.ck12.org/cbook/ck-12-middle-school-life-science-2.0/section/7.13/primary/lesson/tropisms-ms-ls

Math

- Operations and Algebraic Thinking
  - Analyze patterns and relationships
- Measurement and Data
  - Represent and interpret data

ISTE NETS Technology Standards

- Critical Thinking, Problem Solving, and Decision Making
  - Identify and define authentic problems and significant questions for investigation
  - Collect and analyze data to identify solutions and/or make informed decisions

Background Information:
(from https://www.nasa.gov/offices/education/programs/national/summer/education_resources/lifescience_grades4-6/LS_how-do-plants-know.html

Key Terms:

- Centrifugal force: an outward force away from the center of rotation
- Chemotropism: enables plant roots to avoid some toxins and grow toward water and nutrients
- Geotropism or Gravitropism: the effect of gravity on the direction of plant growth
- Gravity: a phenomenon where physical bodies attract with a force proportional to their mass
- Phototropism: the effect of light on plant growth
- Stimulus: a factor that causes a response in plant growth
- Thigmatropism: a plant's response to touch, an example of which is the twining of a vine tendril around an object

Most people think of plants as passive acceptors of their environment. In fact, plants respond to many factors in their physical surroundings such as animals, insects, and even other plants. Complex responses to stimuli such as temperature, light, and moisture enable seeds to germinate at the right time of year and prompt trees to drop their leaves in the fall and send out new ones in the spring. Plants respond to diseases and harmful insects in many ways that limit damage, including the production of chemicals that discourage further attack and signal other plants to be "on guard."

Responses that involve definite and specific movement of the plant are called tropisms (from the Greek word for "to turn"). Any factor that elicits such a response is called a "stimulus." Plants can respond by moving toward the stimulus, a positive response, away from the stimulus, a negative response, or somewhere in between, depending on the nature of the stimulus and the type of plant. Different parts of the same plant can respond differently to the same stimulus. Whatever the response, the same type of plant will always respond to the same type of stimulus in a similar and predictable way. There are a number of different tropisms including chemotropism, which enables plant roots to avoid some toxins and grow toward water and nutrients, and thigmotropism, which is response to touch. An example of thigmotropsim is the twining of a vine tendril around an object. Perhaps the best-known and most studied tropisms are phototropism, response to light, and geotropism, response to gravity. This lesson is designed to help students explore and understand some of the basic plant responses involved in phototropism and geotropism.

Many different explanations have been proposed for why plant shoots grow "up" and roots grow "down." (The growth of roots downward, in the direction of the pull of gravity, is called positive gravitropism, and the growth of shoots upward, away from the pull of gravity, is called negative gravitropism. Other plant parts, such as root hairs and leaves, may exhibit transversal gravitropism, growing perpendicular to the main up-down axis of the plant. Scientists have conducted experiments to clarify this phenomenon since at least the early nineteenth century when A. de Candolle showed that moisture was not the determining factor. British physiologist A. Knight demonstrated that root tips are not pulled downward by their own weight. Others have observed that shoots of plants kept in the dark still grow up and roots still grow down, so light was also ruled out as the sole reason plants grow the way they do. In 1806 A. Knight conducted an experiment that clearly demonstrated the influence of gravity on plant growth. Dr. Knight fixed seedlings to a rotating wheel, thereby subjecting them to the artificial, gravity-like pull of centrifugal force. The plants' roots grew downward at approximately a 45° angle, the result of both centrifugal force and gravity. (The experiment worked whether the wheel was in a vertical or a horizontal position.)

Plants growing on Earth have evolved to respond to many different stimuli to help them orient themselves to their best advantage. As one can discover in the phototropism activity, light is an important factor in determining the direction of plant growth. But gravity, the force that causes bodies to fall to the earth and holds the planets in their orbits about the sun, is also critically important. The effect of light on plant growth is called phototropism. The effect of gravity on the direction of plant growth is called gravitropism. (The effect of gravity on plant growth is often called geotropism because the Earth itself,geo, is responsible for the stimulus. Recently, NASA has begun to use the term gravitropism to describe the effects of the pull of gravity, real or artificial, on the up-down plant growth response.) Together, both forces, light and gravity, are primarily responsible for enabling plants to establish a clearly defined vertical growth axis that puts shoots and roots in their "proper" places. Whereas light causes shoots to grow toward it (and roots to go the other way), gravity has the opposite effect. As you can demonstrate, light can be used to change the direction of a plant's growth, thereby overcoming somewhat the effect of gravity. But in the absence of light, shoots and roots use the force of gravity alone to orient themselves in an up-down direction.

Early experiments in the reduced gravity of space have shown that "tissues of flight plants appeared normal and seedlings differed only in the lack of orientation of roots and shoots." In the absence of gravity, scientists growing plants for experiments rely on the phototropic response to orient plant shoot growth. (The foam pad used in the Space touch. An example of thigmotropsim is the twining of a vine tendril around an object. Perhaps the best-known and most studied tropisms are phototropism, response to light, and geotropism, response to gravity. This lesson is designed to help students explore and understand some of the basic plant responses involved in phototropism and geotropism.

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Garden to help retain the Arcillite rooting medium also helps to keep the roots from inadvertently growing into the light.)

For more background information, see NSBRI's Plants in Space Teacher's Guide athttp://www.bioedonline.org/lessons-and-more/teacher-guides/plants-in-space/

Materials:

Part One

- 1-2 large seeds, such as corn or bean
- Resealable sandwich bag
- Cardboard square, cut slightly larger than the sandwich bag
- White paper towel sheet
- Clear tape
- Metric ruler
- Scissors
- Water
- Follow-up questions worksheet
- Pencil

Part Two (optional if materials are available)

- Space Garden bases
- *Arcillite (Hartz brand kitty litter or Oil Absorb can be used as a substitute)
- De-ionized or distilled water
- Large seeds with an obvious orientation (e.g., bean or corn)
- Strong absorbent paper (filter paper or a large coffee filter)
- Instant-bond "super" glue
- Waxed paper
- Light exclusion chambers (pattern included)
- Black construction paper (for light exclusion chamber construction)
- Black electrical tape (for light exclusion chamber construction to cover seams)
- Scissors
- Camera or materials for sketching
- Plant Data Log (optional)
- Plant Growth Chart (optional)
- Dish drainer (optional)

*Arcillite is heat-treated clay. On Earth, it has several current applications in industry and even in cosmetics. It is often used as a non-clouding, non-nutritive rooting medium for ponds and aquariums. It is also sometimes used as an additive to improve the aeration, water-holding, and nutrient-holding capacities of potting media. Historically, Arcillite (also known as fuller's earth) was used in the textile industry to absorb oils and dyes. In space, Arcillite has been successfully used as a substrate for growing wheat and *Brassica rapa*. Hartz brand kitty litter or Oil Absorb can be used as a substitute for Arcillite.

Advance Lesson Preparation:
Arrange students into groups of 4-6 members per group. Make individual copies of the Follow-Up worksheet, as well as the Plant Data Log (optional) and Plant Growth Chart (optional) for use with the second part of the experiment. Each group needs a copy of the Light Exclusion Chamber Pattern. Also, it is very important to place seeds in water to cover them by at least ½ inch in the second part of the experiment. This should be done 24 hours before setting up the experiment. Be sure to soak enough seeds for students to use as a control as well. Also, soak a few extra seeds that can be used to help monitor seed growth without opening the experimental chambers. A light exclusion chamber should be constructed (as an example). The seeds should stay covered from light while soaking.

Safety:
Have the students wash their hands before and after any lab activity. Clean work areas with disinfectant.

Lesson Presentation: This lesson is conducted over several days. Some steps will take longer than others due to the fact that we are dealing with plant growth. Please plan accordingly.

Part One

1. Engage the students by asking them the question, "Would plants grow differently in space? Why do you think that this would happen?" Allow the class time to brainstorm ideas.
2. Tell the class that they are going to start investigating with an easy experiment involving growing plants to gather some information. Make sure to inform them that this investigation will last over several days and will involve two different parts. The first part is a simple observation of how gravity affects plants here on Earth.
3. Divide the students into the predetermined groups and give each team the materials to conduct Part One of the experiment. Make sure that the students understand that they are responsible for creating an observation chart for the experiment.
4. Instruct the students to fold a piece of a paper towel to fit inside the sandwich bag.
5. Have them moisten the paper towel until it is uniformly damp. Make sure to empty any excess water from the towel and place the towel in the bag.
6. Have the students position one or two seeds on top of and in the center of the moistened towel. The seeds should be visible through the bag. Seal the bag securely.
7. Tell the students to position the bag in the center of the cardboard and secure the corners with cellophane tape. Have them stretch the bag tightly to prevent sagging

and to help hold the seeds in place. The cardboard should be stood upright on its side and leaned against a wall.

8. The students should observe the seed and record its appearance over the next few days on the observation chart.
9. When the first root has formed and grown at least one to two centimeters long, instruct the students to turn the cardboard 90 degrees so that the root is now growing parallel to the ground.
10. The students should then continue to observe and record the root growth for several days on their observation chart.
11. Have the students complete the follow-up questions for Part One. This can be done individually or in a group.
12. Discuss the follow-up questions as a group. (More information is provided in the Summarization section of this lesson plan.)
13. The students will see that gravity does have an effect on root growth of plants; however, there is also another factor that affects how plants grow. Ask students what other factor contributes to the growth of plants. Light plays a role in directional growth of plants as well (phototropism).
14. Discuss with the students the principle of gravitropism and how it can be detected in Earth's gravity using the background information provided.

Part Two (optional if materials are available)

15. Explain to the students that they are going to be designing an experiment to explore the effects of gravity on plant growth. As a scientist, only one variable at a time should be tested to ensure that the effect seen is the result of the variable being tested. Since light is another factor, students will have to design an experiment that separates the effects of stimuli (gravity and light) on plants.
16. Discuss why it is important to be sure to exclude light from the germinating seedlings.
17. Using the pattern, have each group build a light exclusion chamber.
18. Next, have students select seeds (seeds should be uniform in size and the seed coat should be undamaged). The seeds should have been placed in water at least 24 hours in advance of the start of the experiment. Place the seeds under the light exclusion chamber.
19. For each Space Garden base to be used, measure and cut a rectangle from the absorbent paper to fit the entire surface of the Space Garden base (approximately 6.5 X 5.25 inches).

20. Center the foam base on the paper rectangle and draw around it to mark the area in which the plants will be placed.
21. Decide how seeds will be placed on the rectangle. There are many options for placement - just be sure that the hila, or eyes, point in at least the four major directions (up, down, left and right) and that each orientation is repeated several times, either by the same group or for all the groups collectively.
22. Mark the spots for the seed placement within the outlined area on the absorbent paper.
23. Fill the base of the Space Garden almost full with Arcillite. Thoroughly moisten the Arcillite.
24. Remove seeds from the water and dry them thoroughly on paper towels.
25. Spread waxed paper on the work surface under absorbent paper to protect the surface.
26. Using a small amount of non-water-soluble ("super") glue, attach each seed in its assigned place and location on the absorbent paper.
27. After assuring that the seeds are firmly attached, moisten the paper and place it with the seeds (seeds facing out) onto the Space Garden base, aligning the outline drawn earlier with the rim of the well holding the Arcillite.
28. Secure the paper by engaging the snap-close locks at the corners of the Space Garden base.
29. Sketch or photograph the experimental set up, showing the placement of the seeds.
30. Place a light exclusion chamber over the seeds and secure the edges with black electrical tape.
31. Place the entire unit in a vertical position, with the water port facing up. A dish drainer is a handy way to hold the units in place and to protect the table surface from any water that may leak out.
32. One or two control units should be prepared at the same time. If one control unit is used, place it in the vertical position, just like the experimental units. If a second control unit is used, place it in the vertical position but rotated 90° so that it rests on one of the short sides, with the water port facing to the right.
33. Keep some seeds wrapped in a moist paper towel and covered with a light exclusion chamber. Look at these seeds every few hours after the first 48 hours. When roots and shoots have emerged enough that the direction of growth can be determined, the seeds in the experimental chambers are ready for the next step. Do not open the experimental chambers until you are going to change the orientation. This would be the end of the first day.
34. When the monitor seeds show shoot and root growth, open the experimental and control chambers. *(This will be about 48-72 hours after the initial setup.)*

35. Photograph or sketch the seedlings.
36. Working quickly, measure and record the length of shoots and roots. Try not to move or disturb the seedlings' placement.
37. Note the up-down direction of growth. Did the roots and/or shoots change from their direction of initial emergence to reach that orientation?
38. Replace and reseal the light exclusion chamber.
39. Rotate the experimental units so that they stand vertically, resting on a short side with the water port facing to the right. Do not change the orientation of the control unit(s).
40. Wait until the next day to observe the effects of gravitropism by opening the experimental chambers.
41. Photograph or sketch the seedlings.
42. Measure the length of the roots and shoots. Have they grown longer?
43. Have the roots and/or shoots changed their direction of growth? (The answer should be yes.)
44. Have the roots and/or shoots changed their up-down orientation? (The answer should be no. The change in direction of growth should have enabled the seedlings to reestablish their alignment with gravitational pull.)
45. Measure the angle of change in direction in root and shoot growth. The change should be approximately 90° for the experimental plants. The control plants should be unchanged.
46. At the conclusion of the experiment, discuss the results with the class.

Summarization:

Share the individually created data and observation charts as a class, making sure to discuss how the different groups set up their data collection methods. Allow the students time to discuss the observations that were made and what was learned during the activity.

Ask the teams to compare their results of the gravity growth experiment with other teams. Talk about the follow-up questions from both parts of the experiment. (See background information and additional information below.)

Plants respond directly to Earth's gravitational attraction and also to light. Stems grow upward, or away from the center of Earth, and towards light. Roots grow downward, or towards the center of Earth and away from light. These responses to external stimuli are called tropisms. Plants' growth response to gravity is known as gravitropism; the growth response to light is phototropism. Both tropisms are controlled by plant growth hormones.

Indoleacetic acid, or auxin, is a plant hormone that, in high concentrations, stimulates growth and elongation of cells in stems, while retarding the growth of root cells. When auxin is distributed uniformly throughout a stem, all sides of the stem grow at the same rate, thereby enabling the plant to grow toward light and away from gravity. If the plant is tipped over on its side, auxin concentrates on the lower side of the stem, causing the cells on the lower side of the stem to elongate. This process turns the stem so that it once again grows upward, presumably toward the light.

Roots also will change direction when a plant is tipped on its side. Auxin concentrates on the lower sides of the roots and inhibits the elongation of root cells. As a result, root cells on the upper side of the root grow longer, turning the roots downward into soil and away from the light. Roots also will change direction when they encounter a dense object, such as a rock. In these cases, auxin concentrates on the lower side of the roots, enabling the roots to change direction and find a way around the rock so normal growth can resume.

Career Connection: (from http://stemcareer.com/topcareers/ and http://www.onetonline.org/)

Soil and Plant Scientists (Agronomist and Botanist) - Conduct research in breeding, physiology, production, yield, and management of crops and agricultural plants or trees, shrubs, and nursery stock, their growth in soils, and control of pests; or study the chemical, physical, biological, and mineralogical composition of soils as they relate to plant or crop growth. May classify and map soils and investigate effects of alternative practices on soil and crop productivity. Sample job titles include Soil Scientist, Agronomy Research Manager, Crop Nutrition Scientist, Microbiology Soil Scientist, Physical Hydrologist, Research Soil Scientist, and Soil Fertility Extension Specialist.

Agricultural Engineers - Apply knowledge of engineering technology and biological science to agricultural problems concerned with power and machinery, electrification, structures, soil and water conservation, and processing of agricultural products. Sample job titles include Professor, Engineer, Project Engineer, Agricultural Engineer, Agricultural Safety and Health Program Director, Assistant Professor, Research Agricultural Engineer, Research Leader, Agricultural Systems Specialist, and Conservation Engineer.

Nursery and Greenhouse Managers - Plan, organize, direct, control, and coordinate activities of workers engaged in propagating, cultivating, and harvesting horticultural specialties, such as trees, shrubs, flowers, mushrooms, and other plants. Sample job titles include Production Manager, Nursery Manager, Greenhouse Manager, Grower, Propagation Manager, Farm Manager, Garden Center Manager, Harvesting Manager, Horticulturist, and Perennial House Manager.

Evaluation:

- Individually created data and observation charts
- Follow-up questions worksheet
- Teacher observation and assessment of student performance during the activity

Lesson Enrichment/Extension:

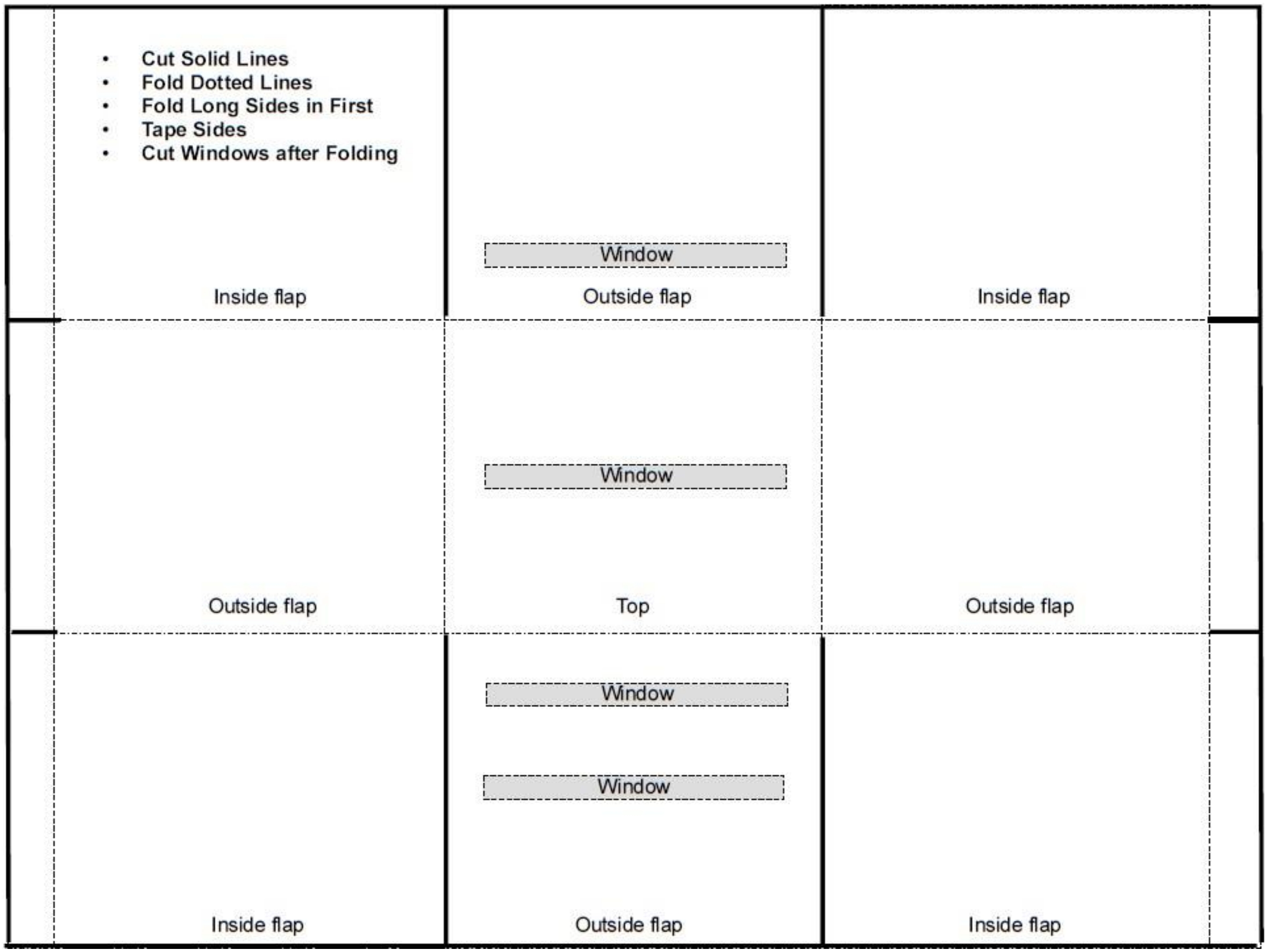
- Try different plants. Do some types of plants respond more strongly than others?
- Reposition the Space Garden in a different way each day and look at the plant form after repeating this several times.
- Demonstrate the interaction between light and gravity. Which is stronger?
- Design an experiment to determine how quickly plants respond to gravity.
- Research the visible waves and the various electromagnetic spectrum waves a https://science.nasa.gov/ems/02_anatomy.
- Show NASA's Space Station Live: Cultivating Plant Growth in Space https://www.youtube.com/watch?v=9MfWARdoF-o&t=90s
- As an additional challenge, set up a device to rotate the chambers – slowly cancel the effect of gravity or more quickly to counteract it.

Associated Websites:

- Teachers and Students Investigating Plants in Space (teacher's guide) http://er.jsc.nasa.gov/SEH/Investigating_Plants_in_Space.pdf
- Investigating Plants in Space http://teacherlink.ed.usu.edu/tlnasa/units/InvestigatingPlants/InvestigatingPlants.pdf
- NASA Science News: Leafy Green Astronauts http://science.nasa.gov/science-news/science-at-nasa/2001/ast09apr_1/
- BioEd Online: Biology Teacher Resources from Baylor College of Medicine Plants in Space Supplemental Resources http://www.bioedonline.org/BioEd/cache/file/17C9D00D-04E6-D078-51E04A622FA1F120.pdf
- Plants in Space Video Clip: Assembly of BRIC units http://www.youtube.com/watch?v=riNaH4busxc
- Do Plants Need Light? A BioEd Lesson http://www.bioedonline.org/lessons-and-more/lessons-by-topic/ecology/food/do-plants-need-light/

2006 NASA Image: ISS013E84325 - View of Spaceflight Participant (SFP), Anousheh Ansari, posing for a photo with barley in a root tray.

Source:
https://www.google.com/search?q=anousheh+ansari+picture+with+a+barley+root+tray&rlz=1C1GCEU_enUS821US821&sxsrf=ALeKk01MBIsS-6wWikEVW7JyuZbxDS-cCw:1592857466067&tbm=isch&source=iu&ictx=1&fir=B0XT7LGkc_AX_M%253A%252CxoonaRD4zlY-TM%252C_&vet=1&usg=AI4_-kRd2nQAzKKvS6bThD3PDlrU_JRSXw&sa=X&ved=2ahUKEwie3MS7oJbqAhWXLc0KHSo3C6UQ9QEwAHoECAoQBQ&biw=1680&bih=979#imgrc=B0XT7LGkc_AX_M:



When done, the light exclusion chamber should look like this.

Plant Data Log

Note: Add units for Temperature and Plant Height

Name ____ *Plant Type* ____

Date	Time	Location	Plant Age (days)	Temperature ( )	Light Source	Photoperiod (hrs of light/ hrs of dark)	Water added (ml)	Plant Height ( )	Notes (flowering, spots on leaves, appearance, etc.)

Plant Growth Chart

(1 square = 0.25 inch x 0.25 inch)

Name ________________________________ Plant Type ________________________________

Days after planting

Name:__________________________Date:_________

Testing a "Tropism"

Part One Follow-up Questions

1. In which direction did the root begin growing?

2. What happened to the root growth when the cardboard was rotated?

3. Based on these observations, would you say that gravity affects the direction of root growth? If so, how?

4. Do you think the roots would grow in the same way on the International Space Station, where gravity's effects are not felt? What differences might there be, and why?

5. If a stem formed during your experiment, in which direction did it grow?

6. What happened to the stem when the cardboard was rotated?

Part Two Follow-up Questions

7. Did the plants all bend by the expected amount? What factors might cause the angle to be different (e.g., not enough time for the plants to adjust; an obstacle in the way; plants not actively growing)?

8. Did some plants not bend? If so, which ones? Why?

9. Did the control plants change their direction of growth or orientation? Explain.

10. Did the plants grow (increase in length)? Did they all grow by the same amount? Why?

11. What is the orientation of the leaves? Do you think the orientation of the leaves is affected by gravity?

12. Were the measurements similar for each unit of the experimental units?

13. Present your results with photos/drawings, narrative description and tables or graphs comparing growth and change in test versus control plants.