How Do Plants Know Which Way to Grow? "Tropisms"

LESSON THEME

This lesson investigates whether plants use the force of gravity to help them know which way to grow. Students gain a better understanding of plant behavior and learn how to apply the scientific method.

OBJECTIVES

Students will

- Explore the effects of gravity on plant growth
- Apply the principles of experimental design, data collection, analysis, and presentation

NASA SUMMER OF INNOVATION

UNIT
Life Science—Plants

GRADE LEVELS
4 – 6

CONNECTION TO CURRICULUM
Science and Mathematics

TEACHER PREPARATION TIME
2 ½ hours

LESSON TIME NEEDED
7 hours over 4 to 5 days

NATIONAL STANDARDS

National Science Education Standards (NSTA)
Science as Inquiry

- Understanding of scientific concepts

Common Core State Standards for Mathematics (NCTM)
Operations and Algebraic Thinking

- Analyze patterns and relationships

Measurement and Data

- Represent and interpret data

MANAGEMENT

Before the actual experiment begins, at least 24 hours before setting up the experiment, you will need to discuss the principle of gravitropism and how it can be detected in Earth's gravity. Discuss why it is important to exclude light from the germinating seedlings. Students should select seeds (seeds should be uniform in size and the seed coat should be undamaged). Place seeds in water to cover them by at least 1⁄2 inch. Be sure to soak enough seeds for the control. Also soak a few extra seeds that can be used to help monitor seed growth without opening the experimental chambers. Assemble light exclusion chambers as needed and place them over the seeds in water. See the actual lesson for step-by-step procedure for each day of the experiment.

CONTENT RESEARCH

MATERIALS

- Space Garden bases
- Arcillite
- De-ionized or distilled water
- Large seeds with an obvious orientation (bean and/or corn)
- Strong absorbent paper (like filter paper, or a large coffee filter)
- Instant-bond "super" glue
- Waxed paper
- Light exclusion chambers
- Black electrical tape
- Camera or materials for sketching
- Dish drainer (optional)

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 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 is response to touch, an example of which 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. The following activities are 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.)

Today we know that plants growing on earth have evolved to respond to many different stimuli to help them orient themselves to their best advantage. As you 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 Garden to help retain the Arcillite rooting medium also helps to keep the roots from inadvertently growing into the light.)

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

LESSON ACTIVITIES

Activity How Do Plants Know Which Way to Grow? "Tropisms"

Students will set up and conduct an experiment to demonstrate the effects of gravity on plant growth. They will consider the difficulties of designing an experiment that separates the effects of stimuli (light and gravity) that have similar responses (directional growth). While slow rotation of seedlings can cancel the effect of gravity, faster rotation can create centrifugal force to compete with it. But equipment for such experiments requires significant construction and expense. A simpler technique for demonstrating gravity is to change the orientation of seedlings germinated in the dark, as will be done in this activity. Students will also consider the problem of controlling variables in order to ensure that the effect seen is the result of the variable being tested.
http://www.spacegarden.net/downloads/Gravitropism.pdf

ADDITIONAL RESOURCES

Gravitropism article discusses plants' ability to align themselves with Earth's gravitational field.
http://www.biologie.uni-hamburg.de/b-online/e32/32c.htm

"Leafy Green Astronauts" Science@NASA article: NASA scientists are learning how to grow plants in space. Such far-out crops will eventually take their place alongside people, microbes, and machines in self-contained habitats for astronauts.
http://science.nasa.gov/science-news/science-at-nasa/2001/ast09apr_1/

"Teaming up on Space Plants" Science@NASA article: Students, scientists, and astronauts join forces to learn more about how plants grow in space.
http://science.msfc.nasa.gov/science-news/science-at-nasa/2001/ast10may_1/

"Plants in Space: Assembly of BRIC Units" is a video that describes the procedure prior to launch of a space experiment with plants, the BRIC PDFU's are assembled under supervision at a laboratory at Kennedy Space Center. The experiment on space shuttle STS-131 examined the role of the cytoskeleton in gravitropism in seedlings of Arabidopsis.
http://www.youtube.com/watch?v=riNaH4busxc

"Growing Space" is an educational magazine that highlights agricultural applications of innovative research conducted during space missions.
http://www.spaceag.org/growingspace.htm

NASA Why? – Plants In Space Video
Files segment explaining how scientists are studying how to grow plants in space.
http://nasa.ibiblio.org/details.php?videoid=6389&start=100&query=SCI%20Files&action=search

NASA KSNN – Plants In Space Video
NASA Kids Science News segment explaining how plants grow in space.
http://nasa.ibiblio.org/details.php?videoid=6452&start=0&query=plants&action=search

DISCUSSION QUESTIONS

Activity: How Do Plants Know Which Way to Grow? "Tropisms"

- What is gravity*? A natural phenomenon by which physical bodies attract with a force proportional to their mass*
- What are tropisms? *Responses that involve definite and specific movement of the plant*
- Have you heard of gravitropism? *Answers will vary. A turning or growth movement by a plant or fungus in response to gravity*

ASSESSMENT ACTIVITIES

Question provided at the end of the lesson: *Answers will vary to questions below*

- Did the plants bend (change direction) in response to gravity?
- Did they all bend by the expected amount?
- What factors might cause the angle to be different? *Not enough time for the plants to adjust; an obstacle in the way; plants not actively growing*
- Did some plants not bend? If so, which ones? Why?
- Did the control plants change their direction of growth or orientation?
- Did the plants grow (increase in length)? Did they all grow by the same amount?
- What is the orientation of the leaves? Do you think the orientation of the leaves is affected by gravity?
- Were the measurements similar for each unit of the experimental units?
- Can we accept the hypothesis? *Seedlings will bend and grow toward in response to gravity*.
- Present results with photos/drawings, narrative description and tables or graphs comparing growth and change in test versus control plants.

ENRICHMENT

- Try different plants. Do some types of plants respond more strongly than others? *Answers will vary*
- Reposition the Space Garden in a different way each day and look at the plant form after repeating this several times. *Observations will vary*
- Have students explore the http://missionscience.nasa.gov/ems/02_anatomy.html Web site to learn more about visible waves and the various electromagnetic spectrum waves**.**
- Show the NASA KSNN & NASA Why videos on Plants in Space: Why Do Plants Grow Upwards?