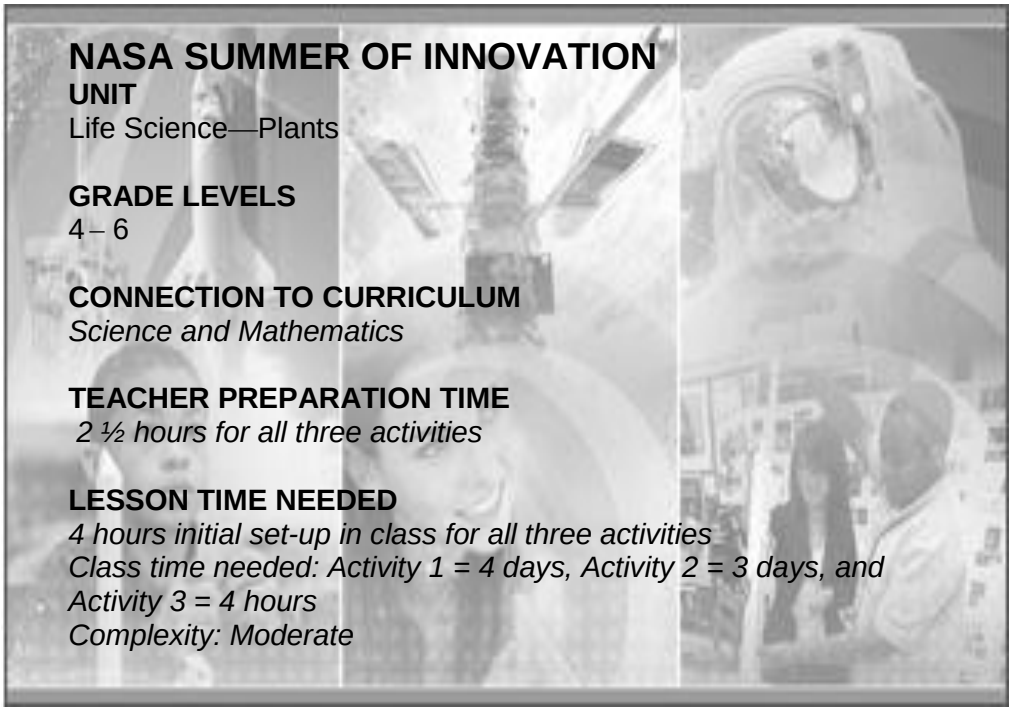
Light Effects on Plant Behavior



NASA SUMMER OF INNOVATION

UNIT
Life Science—Plants

GRADE LEVELS
4 – 6

CONNECTION TO CURRICULUM
Science and Mathematics

TEACHER PREPARATION TIME
2 ½ hours for all three activities

LESSON TIME NEEDED
4 hours initial set-up in class for all three activities
Class time needed: Activity 1 = 4 days, Activity 2 = 3 days, and Activity 3 = 4 hours
Complexity: Moderate

LESSON THEME
This lesson integrates a series of activities, which investigates the principals of photosynthesis and effects of light on plants. Students gain a better understanding of plant behavior and learn how to apply the scientific method.

OBJECTIVES

Students will

- Design their own experimental equipment to carry out a series of simple experiments
- Investigate how red, green, and blue visible wavelengths affect growth functions
- Apply simple geometry to determine light quantity
- Apply the scientific method (prediction, observation, etc.)
- Interpret complex interactions involving three variables
- Investigate basic principle of photosynthesis and how light intensity, distance, and wavelengths effect plant growth

NATIONAL STANDARDS

National Science Education Standards (NSTA)
Science as Inquiry
- Understanding of scientific concepts
- An appreciation of 'how we know' what we know in science
- The dispositions to use the skills, abilities, and attitudes associated with science

Physical Science Standards
- Properties of objects and materials
- Position and motion of objects

Science and Technology
- Abilities of technological design
- Understanding science and technology

Principles and Standards for School Mathematics (NCTM)
Operations and Algebraic Thinking
- Use the four operations with whole numbers to solve problems
- Analyze patterns and relationships

Measurement and Data
- Represent and interpret data
- Geometric measurement: understand concepts of angle and measure angles

Ratios and Proportional Relationships
- Understand ratio concepts and use ratio reasoning to solve problems

Statistics and Probability
- Develop understanding of statistical variability

MANAGEMENT

The activities in this lesson should be done with cooperative groups of two to three students. Safety practices should be reviewed and observed during the activities. Please note that these activities are intended to run 2 to 4 days in duration.

CONTENT RESEARCH

Activity 1 Phototropism: Do Plants Prefer the Blues?

Light is composed of short and long wavelengths. Violet and blue wavelengths are the shortest, and oranges and reds are the longest. All of these waves are essential to photosynthesis, a chemical reaction used by plants to make food. Yellow and green waves are medium in length and do not contribute to photosynthesis. All wavelengths, however, combine to create the natural, white light required for uniform plant growth.

***Activity 2* Phototropism: How Little Light Will Bend a Seedling?**

On Earth gravity is present in the quantity of 1 g (unit gravity). The quantity of light on the other hand can vary enormously from very large quantities of irradiance in the order of 8000 $\mu Em^{-2}s^{-1}$ in sunlight at noon to vanishingly small amounts. With the chamber that you and your students constructed in the phototropism activity, it is easy to Investigate the effects of light quantity on bending of seedlings.

Activity 3 Can Photosynthesis Occur on Saturn?

Photosynthesis is the transformation of light energy into chemical energy. Green leafy plants contain a light-absorbing pigment called chlorophyll. This pigment provides the biological mechanism that drives photosynthesis in plants. Chlorophyll uses the energy from sunlight to convert carbon dioxide

MATERIALS

Activity 1 Phototropism: Do Plants Prefer the Blues?
- Black film can with lid, 35 mm
- One floral foam disc, 28 mm in diameter and 2 to 4 mm thick
- Three grid strips, 0.5 by 4 cm (page 49)
- Three wick strips, 1 by 4.5 cm, made of soft paper toweling (page 49)
- Three brassica or other medium-sized seeds (turnip, lettuce, or alfalfa)
- Water bottle
- Forceps to handle seed
- Hand-held hole punch
- Clear adhesive tape, 2 cm wide
- Black vinyl electrical tape, 2 cm wide
- Three 1.5-cm squares, 1 each of red, green, and blue transparent plastic mylar (Roscolux® films red #26, green #89, and blue #69 work well) or colored acetate from art stores or theatre departments

Activity 2 Phototropism: How Little Light Will Bend a Seedling?
- Four black film cans with lids, 35 mm
- Four floral foam discs, 28 mm diameter and 2 to 4 mm thick
- Four grid strips, 0.5 by 4 cm (page 43)
- Four wick strips, 1 by 4.5 cm, made of soft paper toweling (page 43)
- Four brassica or other similar-sized seeds (turnip, lettuce, or alfalfa)
- Water bottle
- Forceps to handle seed
- Clear adhesive tape, 2 cm wide
- Black vinyl electrical tape, 2 cm wide
- Scissors
- Four 1.5-cm squares of aluminum foil
- Fine needles or pencil point for making holes in aluminum
- Dissection strips (page 23)
- Hand lens
- Hand-held hole punch
- Small plastic protractor or Tropism Response Measuring Card (page 90)

Activity 3 Can Photosynthesis Occur on Saturn?
- Two plastic funnels of the same size and shape (The maximum diameter of the funnels needs to be just enough smaller than the internal diameter of the cups listed below so that the funnels will rest just inside the cup's rim.)
- Two plastic or glass cups that have a slightly larger inner diameter than the funnels' outer diameter
- Two rubber bands
- Two clear drinking straws (a bubble in water in the straw must be visible)
- Plastic cling food wrap
- Salt (1/4 teaspoon for each setup)
- Baking soda (1/4 teaspoon for each setup)
- Water

into glucose, with the production of oxygen as a byproduct. The glucose is used by the plant to produce leaves, flowers, fruits, and seeds. Glucose is also converted into cellulose, which is the structural material used in cell walls.

The “inverse-square law” of physics states that as energy radiates equally in all directions from a source, the intensity (brightness) of the energy decreases at a rate that is proportional to the square of the distance that the energy has traveled. The illumination of a light bulb 4 meters away is only one-fourth as intense as the illumination from a light bulb 2 meters away. Since the inverse-square law says that illumination goes as the reciprocal of the distance squared, a light source twice as far away appears only one-fourth as bright. If it were three times further (6 meters, compared to 2 meters), it would be one-ninth as bright. The inverse-square law is applicable to all forms of electromagnetic radiation as well as to the force of gravity.

Saturn is more than 9 times farther away from the Sun as Earth is from the Sun. As a result, Saturn receives less than approximately 1/81, or 1.2%, of the sunlight that Earth receives. Is this enough sunlight to drive photosynthesis?

Oxygen is used by nearly all multicellular organisms in chemical reactions that break down glucose to “retrieve” the chemically stored Sun’s energy. The energy is used for growth and other living functions. Using oxygen is much more efficient than using reactions that break down glucose without oxygen. When Earth first formed about 4.5 billion years ago, there was no oxygen in the atmosphere. The evolution of photosynthesis was necessary for the buildup of atmospheric oxygen that made complex life possible.

Key Terms:
Cellulose: the structural material used in cell walls
Chlorophyll: light-absorbing pigment in plants that drives photosynthesis
Glucose: used by the plant to produce leaves, flowers, fruits, and seeds
Gravity: present in the quantity of 1 g (unit gravity)
Inverse Square Law: states that as energy radiates equally in all directions from a source, the intensity (brightness) of the energy decreases at a rate that is proportional to the square of the distance that the energy has traveled
Light: the visible portion of energy from the Sun
Oxygen: a byproduct of photosynthesis
Phototropism: the way light affects the direction a plant grows
Photosynthesis: a chemical reaction used by plants to make food

LESSON ACTIVITIES

Activity 1 Phototropism: Do Plants Prefer the Blues?

Activity illustrates how plants use various colors (wavelengths) of light for different tasks. Activity is located in the “Teachers and Students Investigating Plants in Space” educator guide, page 86
http://virtualastronaut.tietronix.com/teacherportal/pdfs/InvestigatingPlantsinSpace.pdf

A*ctivity 2* Phototropism: How Little Light Will Bend a Seedling?

Investigate the effects of light quantity on the bending of seedlings. Activity is located in the “Teachers and Students Investigating Plants in Space” educator guide, page 88

http://virtualastronaut.tietronix.com/teacherportal/pdfs/InvestigatingPlantsinSpace.pdf

Activity 3 Can Photosynthesis Occur on Saturn?

Activity teaches the basic principle of photosynthesis and how light intensity diminishes as a function of distance from the light source. Observations are made over an extended period, although the activity set-up

may take place in a shorter period of time. Activity originated from NASA Educational Brief Cassini Science Investigation Can Photosynthesis Occur on Saturn?

http://solarsystem.nasa.gov/docs/Can_Photosynthesis_Saturn.pdf

ADDITIONAL RESOURCES

Growing Space is an educational magazine written for sixth-grade science students that highlights agricultural applications of innovative research conducted during space missions. Growing Space has been cross-referenced to learning standards established by the National Science Teachers Association.
http://www.spaceag.org/growingspace.htm

Our World: Plants in Space Video
Find out how plants use light to make their own food in a process called photosynthesis. See how NASA uses LED lights to help grow plants in space. Design your own plant growth chamber like the ones used by NASA.
http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms=plants

NASA SciFiles: The Case of the Prize-Winning Plants
http://scifiles.larc.nasa.gov/educators/episodes/2003_2004/Winning_Plants_4.pdf

NASA Why? – **Plants In Space Video**
Files segment explaining how scientists are studying how to grow plants in space
Location: 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
Location: http://nasa.ibiblio.org/details.php?videoid=6452&start=0&query=plants&action=search

DISCUSSION QUESTIONS

Activity 1 Phototropism: Do Plants Prefer the Blues?

Question: A Phototropic Riddle

- If you were a plant or a plant were you, which hue would you choose to tie your shoe? Is it red, green, or blue? *Answers will vary*
- Are there different colors of light coming from the Sun? *yes*
- What are the colors*? In visible light red, orange, yellow, blue, green, and purple*
- Do you think plants use each color differently? *Yes*
- Do you think NASA uses these differences in their studies? *Yes, NASA uses all the light from a star even the ones we cannot see. The light is referred to as the electromagnetic spectrum and NASA uses all forms of light to gain better understandings of objects in space.*

Activity 2 Phototropism: How Little Light Will Bend a Seedling?

- Does the amount of light effect the direction a plant turns? *Yes, plants will try to reach towards the light if it is not getting a proper amount.*
- How much light do you think is needed to bend a seedling*? In order to get a seedling to bend or reach in a certain direction you much limit the plants access to light and have light coming from one direction. The seedling will reach (or bend) towards the light's direction.*

Activity 3 Can Photosynthesis Occur on Saturn?

- Are there plants on Saturn*? No, Saturn doesn't have a surface or other materials a plant needs to grow.*

- Does Saturn have O_2? *No*
- When Earth first formed about 4.5 billion years ago, there was no oxygen in the atmosphere. How do you think O_2 was formed*? O_2 became abundant in the Earth's atmosphere from plant photosynthesis.*

ASSESSMENT ACTIVITIES

Activity 1 Phototropism: Do Plants Prefer the Blues?

Concluding Activities and Questions
In this activity students will have observed the effects of light in orienting the growth of seedlings in the presence of gravity. Have students consider the following:

- What will happen to the seedlings if you darken the windows? What will happen if you darken only the blue window? *Recently plant physiologists have isolated minute amounts of a yellow molecule called flavochrome that absorbs blue light and is active in the signal transduction pathway that transmits energy from the blue light to the bending response.*

Activity 2 **Phototropism: How Little Light Will Bend a Seedling?**

See activity for diagrams and questions for assessment

Activity 3 Can Photosynthesis Occur on Saturn?

Questions
- Based on the data collected, is the amount of sunlight available on Saturn enough to drive photosynthesis? *No*
- What is the purpose of adding baking soda to the water? *To add CO_2*
- What is the purpose of adding salt to the water? *salt provides osmotic balance for the water*
- What other environmental factors influence photosynthesis? Temperature? What are other chemicals present in Earth's atmosphere? *Nitrogen, O_3, answers will vary*
- Saturn and its satellites are far enough away from the Sun that sunlight reaching the system is greatly reduced. Gravitational flexing, internal radioactive decay, and chemicals like methane and ammonia may yield more energy on Saturn than sunlight. Could plant life adapt to any of these energy sources? *Note that this is a VERY open-ended question*
- Where on Earth does photosynthesis occur at a light intensity greatly reduced from the light intensity on the surface? *Ocean depths*
- How would you change the experiment to test the possibility of photosynthesis on Mars, which is about 1.5 times as far from the Sun as is Earth? *Answers will vary*
- Based on your experimental results and the background material, what do you think the chances are for the existence of large, complex living organisms in the outer solar system (Saturn and beyond)? *Answers will vary*

ENRICHMENT

Activity 1 Phototropism: Do Plants Prefer the Blues?

- 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**.**

Activity 2 **Phototropism: How Little Light Will Bend a Seedling?**

- Have students read the mission information "Microgravity effects on pollination and fertilization" located at the end of the activity for more information on NASA's study of plants and their behavior.

- Show the NASA KSNN and NASA Why videos on Plants in Space.
  http://www.fastplants.org/pdf/activities/light_bend_seedling.pdf

Activity 3 Can Photosynthesis Occur on Saturn?

- Baking soda provides carbon dioxide (after dissociation from sodium bicarbonate) to drive the light-independent chemical reactions of photosynthesis forward. The addition of salt provides osmotic balance for the water. More advanced students can research the distinction between the light dependent reaction and the light independent reaction of photosynthesis and write the chemical equation for each reaction.
- Select Saturn videos from http://saturn.jpl.nasa.gov/video/ for background information on Saturn.