SPACE SEEDS

FACILITATION GUIDE

Facilitate two hands-on, guided experiments investigating the effects of light and orientation on the germination and growth of seedlings.



Scan to view activity

CLOVER by 4-H

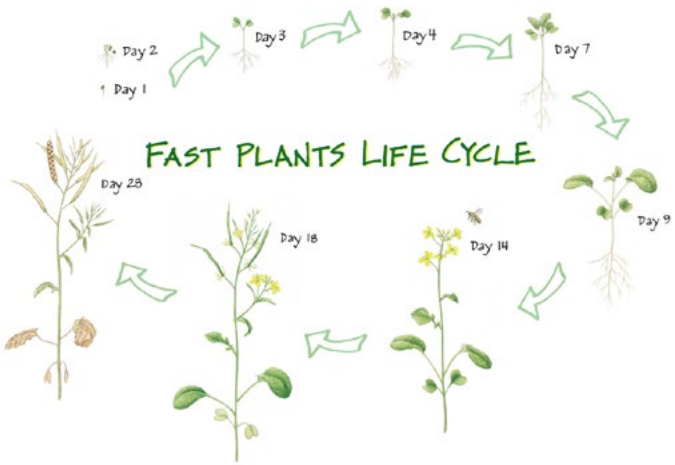
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SPACE SEEDS

FACILITATION GUIDE

Science Standards

Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively (Next Generation Science Standard MS-LS1-4).



Objective

To observe the effects of light and orientation on the germination and growth of seedlings.

Materials

Deli Containers:
4 (8 oz) with lids

Paper Towels:
Thick *(e.g. Bounty brand)*

Seeds:
Packet of 100 Rapid Cycling Brassica rapa seeds
(e.g. Standard Wisconsin Fast Plants®® seeds)

Scan to purchase seeds

Water:
Spray bottle or dropper

Aluminum Foil

Ruler *(optional)*

Light Source:
Windowsill or countertop with indirect or direct sunlight

ABOUT EMILY

Emily Calandrelli, an MIT aerospace engineer, author, and host of Emily's Wonder Lab, has spent her career making science exciting and accessible. Now, she's taken her passion to new heights! She became the 100th woman to fly to space as a crewmember aboard Blue Origin's NS-28 mission. In collaboration with Wisconsin Fast Plants®, Emily brought along a science experiment to investigate how gravitational changes influence plant growth - a critical area of research for sustaining human life on long-term space missions.

As you guide youth through this activity, you are connecting them directly to the same scientific questions being explored in space. Just as Emily's experiment examines how plants respond to microgravity, your students will investigate how light and gravity shape plant growth here on Earth. By engaging in this hands-on experiment, youth will experience the scientific process firsthand, making real observations and drawing conclusions just like researchers do. This is more than just a classroom activity—it's an opportunity to inspire the next generation of scientists, engineers, and explorers, showing them that the work they do today is part of a much bigger story of discovery and innovation, both on Earth and beyond.

View video about Emily Calandrelli's adventure in space.



Click to watch video

Scan to view Emily Calandrelli's channel

What are Fast Plants® and why are scientists excited about them?

Wisconsin Fast Plants® are like the superheroes of the plant world because they grow quickly. Scientists and students use them to learn how plants grow, change, and pass down traits—similar to children inheriting their parents' eye color. Because they grow so fast, we don't have to wait months or years to see what happens.

Scan to view Fast Plants® back story

GERMINATION EXPERIMENT

1. Preparation:

a. Cut paper towel circles (~4-5 inches in diameter) to fit the bottom of the deli containers.



b. Place and then thoroughly moisten the paper towel circles in the bottom of the deli containers.

Fun Fact

Gardening for health...in space! Astronauts are encouraged to take care of plants in space because "space gardening" can help them feel good and connected to Earth.

2. Setup:

a. Place ~25 seeds spread out around the moistened paper towel so they all have some room to grow in each of the 4 deli containers.

b. If needed, gently add a bit more water or drain off the excess to ensure the paper towel is thoroughly wet and seeds are not submerged or floating in water.

c. Put lids on all the deli containers.

d. Gently wrap 2 containers in aluminum foil to create a dark environment; leave 2 containers uncovered for light exposure.





e. Place all deli containers in a warm location, making sure those that are unwrapped are in either direct or indirect sunlight (e.g. a windowsill).



3. Observation & Reflection:

a. Observe changes in the Fast Plants® seedlings exposed to light over the next 4-5 days. Gently add water to the deli containers that are in the light as needed to be certain the paper towel and seeds never dry out.

Note: *The deli container wrapped in foil and kept in the dark typically needs no additional water, so they can remain wrapped until Day 5.*

b. Ask youth what they already know about how plants use light and how much they think the wrapped and unwrapped plants might grow over the next 4-5 days.

c. On Day 5, unwrap the containers kept in the dark and make comparisons with those given light.

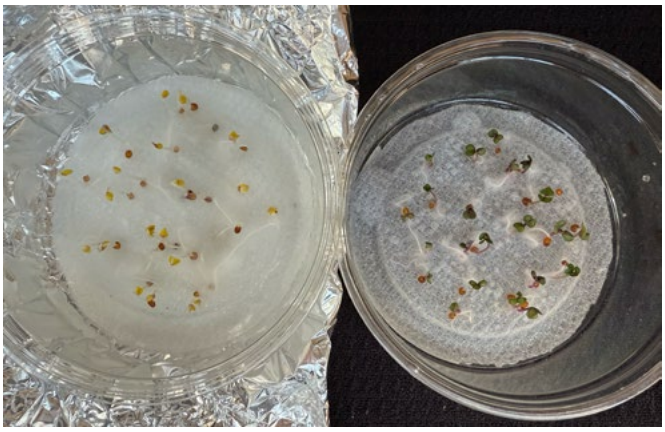
Fun Fact

Rapid Cycling Brassica rapa (aka Fast Plants®) can grow from seed to flower in as little as 14 days, making them an excellent model for studying plant life cycles.

4. Discussion:

a. How did the light and dark conditions affect germination?

b. How did the seedlings respond to their environmental conditions?



Fun Fact

Space Seeds Have Been to the Moon!
During the Apollo 14 mission in 1971, astronaut Stuart Roosa carried tree seeds into lunar orbit. These seeds were later germinated on Earth, resulting in "Moon Trees" planted across the United States. nssdc.gsfc.nasa.gov

Growth Mindset

- Discuss what happened when the seeds were given a challenging environment and lacked resources.
- Ask youth to relate this to a time when they were in a challenging environment.
- How did it affect their growth or progress?

GRAVITROPISM EXPERIMENT

1. Preparation:

a. Add water to all deli containers (without flooding); then, re-wrap with aluminum foil the same deli containers that were given the dark treatment.

b. Select one light-exposed and one dark container for experimental treatment.

2. Setup:

a. Position the chosen containers on their sides (vertical orientation), and use a marker to mark the top position. Use pencils, erasers or something similar to keep the deli containers from rolling, so the top mark remains on top.

b. Leave the remaining containers (one dark and one light) in the horizontal position as controls.



3. Observation & Reflection:

a. Observe again after 6-24 hours (can be left over the weekend – best if placed in a cool location that remains 35-55°F if left longer than 36 hours, as in a refrigerator).

b. Open containers and compare growth directions observed in those containers kept horizontal with those turned vertically, and those in the light compared to those in the dark.

c. Document observations (changes in stem/root direction) and take photos if possible. Discuss ideas about how the seedlings respond to changes in their environments.

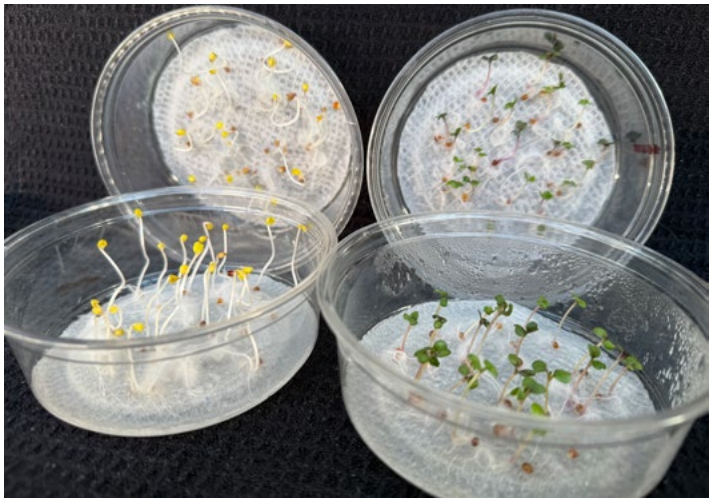
d. Re-wrap the 2 deli containers in the dark treatment group.

e. Rotate the same 2 containers that were turned vertical (one in light and one wrapped and kept dark) 90 degrees clockwise from where the top was previously oriented. Leave the two control containers horizontal (one light and one wrapped).



f. After 6-24 hours in this rotated position, again make observations. Compare all four containers, and compare the vertically-oriented, then rotated light and dark containers with observations made before rotation.

Gravitropism Experiment Continued...



4. Discussion:

a. How did the seedlings respond to changes in their positions relative to gravity and light?
b. How did the seedlings respond to their different environmental conditions?

Fun Fact

Oldest Viable Seed Ever Grown
In 2005, scientists in Israel successfully germinated a 2,000-year-old Judean date palm seed discovered at Masada in the 1960s.
guinnessworldrecords.com



By Benjitheijneb - Own work, CC BY-SA 3.0
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Reflection Questions

- How did gravity and light influence the direction and types of growth observed?
- How do these types of experiments help us understand information that is important for space exploration?

Relationships Help Us Thrive

Just like plants need sunlight to grow, humans thrive best when we seek out and engage with relationships that let us know we belong. Ask youth when and where they feel accepted and included.

4-H
THRIVING MODEL CONNECTIONS

- Help youth to discover how scientific research in general—and plant science specifically—benefits people and the world.
- Discuss with youth what sparked their curiosity today, formulating a list of search terms they might use to research related topics of interest (e.g. science experiments in space, plant experiments, growing food in space, hydroponic systems, etc.)
- Encourage youth to research additional seed or plant experiments that could be conducted at home.
- Discuss why having a growth mindset is essential for research scientists.
- Encourage youth to share what they've learned with family, friends, or their 4-H club.

Fun Fact

We did not always have plants that could grow through their entire lifecycle so quickly. Did you know that Paul Williams, a professor of plant pathology and the inventor of Fast Plants®, spent about 20 years developing them in a lab? That's a long time! Having a growth mindset helped him to learn from his mistakes and keep trying. Over time, his experiments reduced the growing cycle from 6 months to 5 weeks.



CAREER CONNECTIONS

A **plant scientist** is someone who studies plants to understand how they grow, survive, and interact with the environment. If you're interested in nature, love problem-solving, and want to help improve the world by taking care of plants, this might be the right career for you. Plant scientists work in labs, fields, and farms, helping to create better crops, protect forests, and solve environmental issues.



As a plant scientist, you will:

- **Study Plant Growth:**
  Research how different factors like water, sunlight, and soil affect plant health and growth.
- **Conduct Experiments:**
  Test out new ways to grow crops or protect plants from diseases and pests.
- **Improve Food Production:**
  Work with farmers to create better and more sustainable ways to grow food.
- **Contribute to Environmental Conservation:**
  Develop solutions to protect forests, endangered plants, and ecosystems.
- **Collaborate with Other Scientists:**
  Share findings with other researchers and work together on large projects that help improve agriculture and conservation.

There are a lot of careers that have contributed to developing Fast Plants® and other major discoveries. A lot of different types of scientists and experts worked together—like a **team of plant superheroes!**

Geneticists – Think of them as the **codebreakers** of life! They study how traits are passed from parents to their offspring, helping us understand things like why some plants grow faster, resist diseases, or have bigger seeds.

Pollination Experts (Ecologists & Entomologists) – These scientists study how **bees and insects help plants reproduce**. Fast Plants® are used to understand pollination and how to protect pollinators, which is essential for growing food.

Farmers & Agricultural Scientists – They use what we learn from Fast Plants® to grow **better, stronger, and healthier crops** that feed people around the world.

Science is like a puzzle, and Fast Plants® help us put the pieces together. Whether you're growing plants, studying genes, protecting pollinators, or teaching others, YOU can be part of making the world a better place!

BACKGROUND INFO

Overview of Seeds and Germination

Seeds are tiny, yet powerful, packages that contain all the ingredients a new plant needs to get started. They hold the embryo (the baby plant), stored food to fuel early growth, and a protective seed coat. When conditions are right, the seed "wakes up" and begins to grow through a process called germination.

Key Factors in Germination



Water
Water is essential because it softens the seed coat and activates enzymes that kickstart the growth process. Think of it as the spark that ignites the seed's inner engine.



Temperature
Every seed has a preferred temperature range that promotes successful germination. Most seeds do best in warm conditions, which help speed up the chemical reactions needed for growth.



Oxygen
Like all living things, seeds need oxygen for cellular respiration, a process that converts stored food into energy. Even before a seed begins growing, it needs a small amount of oxygen to fuel its metabolism. Once the seed germinates and its seedling emerges, the seed leaves (aka cotyledons) are unfurled like solar panels to collect energy from light that the seeding uses to make its own food, using CO_2 and water molecules. The tiny embryo in the seed depends on food that was stored with it when its mother plant developed the seed and uses oxygen to make use of that stored food. Then, as soon as it emerges into the light after germination, it immediately begins to make its own food.



Gravity
Gravity helps orient the growing seedling by guiding the embryonic root downward into the soil. This natural pull ensures the seedling anchors properly and can access water and nutrients, much like a built-in navigation system.



Light (in some cases)
This experiment shows that Brassica rapa seeds can germinate without light (not all seeds can). However, without light, the newly emerged seedlings spend their reserves of matter and energy contained in the seed to grow elongated stems, searching for light. This process is called etiolation and happens in nature when seeds germinate under a deep pile of leaves, for example, and have to struggle to reach the surface where their tiny seed leaves (aka cotyledons) finally reach the light and are able to start making food for the seedling through photosynthesis.

BACKGROUND INFO

How This Experiment Ties In

This experiment demonstrates these concepts in action. By manipulating conditions, participants will see firsthand how seeds react to their environment. It's a hands-on way to connect science with real-life applications in agriculture and even space research, where understanding plant growth in controlled environments is key.



Why it Matters

- **Inspiring Curiosity:**
  Seeds are a gateway to exploring broader scientific themes—from biology to environmental science. This simple experiment can spark questions about how life begins and adapts.
- **Agricultural and Space Relevance:**
  For agriculture, knowing how to nurture seeds leads to better crop production and food security. In space research, experiments with seeds help us learn how plants might grow in environments beyond Earth, supporting future space exploration.
- **Empowering Future Scientists:**
  By engaging with these concepts, youth can see that science is not just about memorizing facts—it's about exploring, questioning, and discovering how our world works, whether on Earth or in space.

BACKGROUND INFO

Germination: Awakening Life

Matter and Energy Transformations

Germination marks the transition from a seed's dormant state to active growth. Although a seed is in a state of pause, it contains an embryo and stored energy that await the right conditions—primarily water, oxygen, and an appropriate temperature—to reactivate growth.

The Role of Water

Water acts as the "on" switch. As a dry seed imbibes water, its cells hydrate and enzymes become active. These enzymes break down and loosen cell wall structures, allowing cells to enlarge. This process eventually leads to the cracking of the seed coat and the emergence of the radicle, the first embryonic root. The rapid development of root hairs then increases the surface area, enhancing water uptake.

Growth of the Seedling

In *Rapid Cycling Brassica rapa* and many other dicots, the absorption of water also drives the elongation of the embryonic stem (hypocotyl). This growth pushes the seed leaves (cotyledons) and hypocotyl upward. Once the cotyledons emerge, they expand, shed the protective seed coat, and turn green as they become photosynthetically active. At this point, the seedling transitions from relying solely on its internal energy stores to using energy harnessed from light.

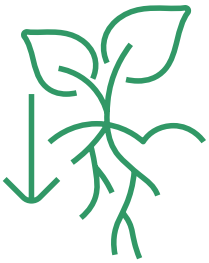
Germination in the Dark: Etiolation

Not all seeds receive light immediately. Some seeds may start buried under soil or layers of leaves and plant material. In such cases, seedlings continue to rely on their stored nutrients, triggering a hormone-mediated response known as etiolation. In etiolation, the plant elongates its stem rapidly, delays or stops chlorophyll production, and stunts leaf growth. These adaptive responses are crucial for survival until the seedling reaches a lighted environment.



BACKGROUND INFO

Gravitropism and Microgravity: Navigating Space



Gravitropism on Earth

Gravitropism (also called geotropism) ensures that plant roots grow downward into the soil, anchoring the plant and accessing water and nutrients, while shoots grow upward toward light. This process involves specialized cells called statocytes located in the root caps and shoot tips. Statocytes contain dense, starch-filled organelles known as statoliths. Under the influence of gravity, these statoliths settle, helping the plant sense its orientation.

If a plant is repositioned, the statoliths shift due to gravity, signaling the plant to adjust its growth direction through auxin redistribution.

Exploring Microgravity

Microgravity is a condition where gravity's effects are significantly reduced, often experienced in space aboard the International Space Station or during parabolic flights. In microgravity, although a small gravitational force still exists, its influence is minimal compared to Earth. This environment allows scientists to study plant growth without the full pull of gravity, revealing how plants might adapt in space. These studies are critical for future space exploration, as they help scientists develop strategies for growing food beyond Earth.

Why Study These Processes?

Understanding both phototropism and gravitropism is key to advancing our knowledge of plant biology on Earth and in space. For agriculture, these insights improve crop management and yield. In space exploration, they pave the way for sustainable life-support systems by ensuring astronauts have access to fresh, nutritious food grown under unique conditions.

Phototropism: Growing Toward the Light



Understanding Phototropism

Phototropism is the process by which plants orient their growth toward light. When a plant is exposed to an uneven light source, growth hormones called auxins distribute unevenly. The cells on the side of the plant that is farther from the light grow more rapidly, causing the plant to bend toward the light source. This directional growth ensures that the plant maximizes its ability to capture sunlight for photosynthesis.

A Balance with Gravitropism

While phototropism drives a plant's movement toward light, gravitropism guides how plants grow in response to gravity. Together, these responses help plants find the best orientation for optimal growth.

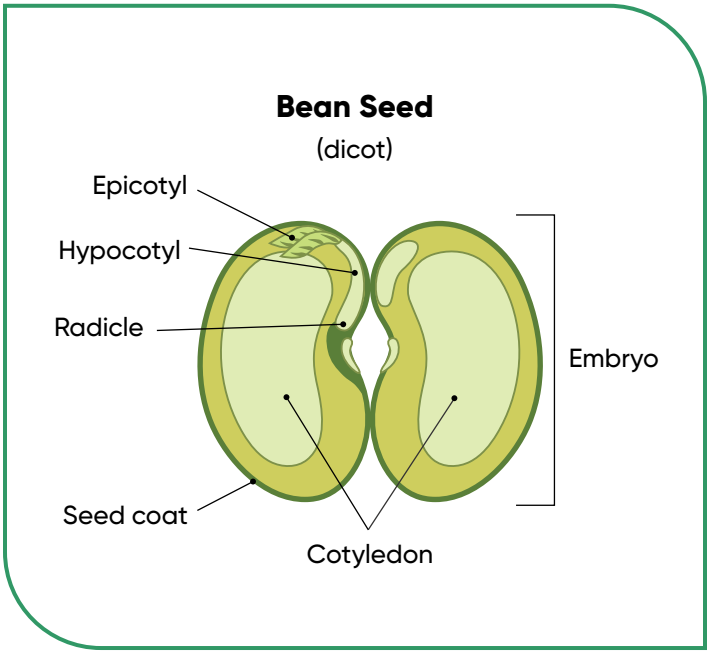
GLOSSARY

Auxins: a plant hormone that regulates plant growth and development.

Brassica Rapa: a plant species in the mustard family (Brassicaceae) that includes a variety of common crops, such as turnips, rapini (also called broccoli raab), Chinese cabbage, and field mustard. Rapid Cycling varieties of Brassica rapa were developed by plant scientists through selective breeding to be a model organism with a very short life cycle for use in research and education.

Cellular respiration: a process that converts stored food into energy.

Chlorophyll: a green pigment, found in the chloroplasts of plant cells, that absorbs light to power the chemical reactions that turn carbon dioxide and water into glucose, providing energy for the plant.



Cotyledons: the part of the seed embryo that forms the first leaves during germination and provides nutrients to the young plant as it starts to grow.

Dicot or dicotyledon: a flowering plant with two seed leaves in its embryo.

Embryo: a baby plant in the early stage of development inside a seed, consisting of the basic structures that will grow into a mature plant: the radicle (embryonic root), the hypocotyl (stem-like structure), cotyledons (seed leaves), and the epicotyl (upper part of the stem and leaves).

Energy: In general, energy is the ability to do work or to cause a change. Plants primarily get their energy from sunlight through photosynthesis. During photosynthesis, they use sunlight to convert carbon dioxide and water into glucose and oxygen. The glucose produced is a form of chemical energy that plants use to grow and carry out essential functions.

Epicotyl: the part of a plant embryo that will grow into the upper part of the stem and the leaves.

Etiolation: a hormone-mediated response that causes a plant to grow adaptively in the absence of light. The plant elongates its stem rapidly, delays or stops chlorophyll production, and stunts leaf growth because it cannot perform photosynthesis properly.

GLOSSARY

Geotropism: see gravitropism.

Germination: the process of transitioning from a seed's dormant state to active growth.

Glucose: a form of sugar and source of energy for plants.

Gravitropism: Also called geotropism, gravitropism is a plant's directional growth response to gravity, whereby roots grow downward toward the Earth's gravitational pull and shoots grow upward, away from gravity, to reach for sunlight.

Hypocotyl: the embryonic stem.

Matter: anything that has mass and takes up space. Plants are composed of matter, take in matter from their environment (water, carbon dioxide, and minerals), transform matter through processes like photosynthesis, and release matter (oxygen) into their environment.

Microgravity: a condition in which people or objects appear to be weightless due to significantly reduced gravitational force.

Photosynthesis: the process that plants use to make their own food by converting sunlight into chemical energy. They take in carbon dioxide and water, and with the help of sunlight, turn them into glucose and oxygen.

Phototropism: the process by which plants orient their growth toward light.

Radicle: first embryonic root.

Root hairs: tiny, hair-like extensions that grow from the surface of a plant's roots, helping the plant to absorb water and nutrients from the soil.

Seed coat: the protective outer layer of a seed that shields the embryo inside.

Statocytes: specialized plant cells that detect gravity and play a key role in gravitropism.

Statoliths: specialized, dense, starch-filled organelles found inside statocytes (gravity-sensing cells). When the plant is affected by gravity, the statoliths shift within the statocytes, allowing the plant to sense which direction is "down."

RESOURCES & ACKNOWLEDGEMENTS

Thank you for joining us for this Space Seeds experiment, and thanks to all who helped make it possible!

Be sure to check out Emily Calandrelli's (The Space Gal) experiments as flown on Blue Origin!
https://fastplants.org/2024/11/18/fast-plants-in-space/

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