Plants in Space

Overview: Discovering an efficient way to grow plants in space is critical for expansion into the extraterrestrial frontier. Space travelers will need a reliable source of renewable food and oxygen to survive over long periods of time. Traditional gardening techniques are not a good match for conditions in spacecraft and space stations so scientists are challenged with creating new growing systems.

Grade Level/Range: Grades 4 to 8

Objective:

Students will:

- Contemplate the challenges of growing plants in space
- Learn about hydroponics and experiment with different hydroponics systems
- Brainstorm other ideas for growing plants in space

Time: 1 to 2 hours for initial planting and discussion, multiple weeks to observe plant growth

Materials:

- containers of various sizes
- light weight growing medium such as perlite or rock wool
- hydroponic nutrient solution
- cotton or nylon wick
- lettuce plants
- potting soil

Background Information:

There's no question about it — plants are vital to our very existence. They provide us with food, oxygen, and shelter. But have you ever stopped to think about how these benefits would translate beyond our planet?

Traveling with plants is not a new concept. Early explorers and colonists coming to the Americas frequently packed clippings of and seeds from their favorite green friends. Growing plants from their native lands provided travelers with familiar sources of food and medicine and also helped with another common ailment: homesickness. Plants can provide similar benefits to astronauts. Plants provide:

Food

Currently NASA compares its food system for astronauts to a picnic because space travelers must pack everything they consume. Their meals include few if any fresh fruits and vegetables due to limited room and rapid spoilage. But as we use the International Space Station, and someday have an outpost on the moon and colonies on Mars, we'll need a renewable food source that will be more economical than "packing groceries." Besides, fresh produce provides nutrients, flavor, texture, and variety to meals that break the monotony of packaged foods.

Air

Plants use carbon dioxide (CO2, produced by astronauts) and produce oxygen (O2, consumed by astronauts) through the process of photosynthesis. They also remove chemical pollutants from the air. Plants would improve the air quality inside spacecraft.

Water Purification

It costs about $22,000 per kilogram to ship objects into space! This makes water, at about 3 kilograms per gallon, a very expensive commodity, so creating a way to reuse water would be very beneficial. Plants can play a role because they produce pure water in the process of transpiration. Scientists are developing techniques to irrigate plants with wastewater— such as that from washing — and then recapture the purified water given off during transpiration.

Waste Recycling

Scientists are also investigating ways to recycle human waste and inedible plant matter to provide nutrients for plants. This is an important element for creating a self-contained ecosystem.

Lifting Spirits

The psychological benefits of plants are hard to measure, but they're clearly evident. Just as parks and other green spaces help urban dwellers unwind and rejuvenate, astronauts surrounded by metal and plastic within a cramped space benefit greatly from the presence of plants. Horticultural experiments are incorporated into missions not only to advance knowledge and technology, but also to provide astronauts with a little connection to home. While producing food in space is serious work, the act of gardening provides enjoyment, relaxation, and recreation.

There is no argument among space scientists about the benefits of leafy green "astronauts," but finding efficient and successful ways to grow plants in space is one of their biggest challenges.

Laying the Groundwork:

- Ask students, what do plants need to grow? *Plants grown in space have the same needs as those grown here on Earth — water, air, light, nutrients, and a place to grow.*
- Can all of these plant needs be met on a spacecraft? What are some of the challenges of providing for these needs? Share the information from the following chart:

Plant Need	Why Important	Challenge in Space
Water	Water is required for photosynthesis (production of food) and transpiration (evaporation of water from leaves into the air, cooling the plant and creating pressure to move water from roots to leaves); it also aids in the absorption of some nutrients.	Water is heavy to transport, so astronauts pack only the amount they need for survival. In low gravity, traditional watering is not an option because water droplets bounce off the soil surface. Water must be directly applied to and absorbed by growing media, or incorporated into the media.
Air	Plants take in carbon dioxide (CO2) and oxygen (O2) to use during photosynthesis. People provide carbon dioxide through respiration.	Air doesn't circulate naturally in space. The oxygen released by plants during photosynthesis can accumulate around them and lead to plant death unless fans keep the air moving. Other gases harmful to plants can also collect inside spacecraft and must be removed.
Light	Plants capture light energy for use in photosynthesis, the process by which plants make food.	Spacecraft have few windows, so growing plants requires artificial light. Lights must be energy efficient to avoid overtaxing limited energy resources.
Nutrients	Plants require certain minerals for proper biological function and growth. Nutrients occur naturally in soil on Earth as a byproduct of the decomposition of organic matter or they can be added through applications of fertilizer. (Fertilizer is sometimes referred to as "plant food," but because plants make their own food through the process of photosynthesis, fertilizer should more accurately be compared to a multivitamin.)	Lunar and martian ground lacks the nutrients plants need, so nutrients must be brought to these sites. Scientists are investigating ways to recycle waste to provide nutrients for plants.

Growing Media	Plants need somewhere to grow. On Earth, most crops grow in soil.	The weight of traditional garden soil and potting mixes makes them impractical in space. Scientists are experimenting with different media such as gels and soilless mixes, along with techniques like hydroponics to devise an acceptable alternative to soil. Additionally, the low-gravity environment changes the way roots, shoots, and water behave in space, so the design of growing containers must help plants overcome the effects of reduced gravity

- What kind of technologies could be developed to help plants grow in space? *Scientist can create growing systems to provide acceptable environmental conditions (e.g., plant-growth chambers and greenhouses); they can select specific characteristics from existing plants and using them to breed new varieties better suited to growing in space; or they can engineering plants that are adapted to the space environment.*
- What kind of characteristics would an ideal space plant have?

Ideal space plants would be:

- short
- grow in low light
- have few inedible parts
- grow quickly and produce a reliable harvest
- resist disease
- need little water and few nutrients
- need little maintenance
- yield a lot of oxygen.

Exploration:

1. To inspire students to begin thinking like the scientists searching for innovative ways to grow plants in space, create a demonstration of a non-traditional growing technique using hydroponics.

   Soil is both heavy and bulky which – two qualities to avoid when packing for space travel. Hydroponics growing techniques place plants in alternate mediums and then use water solutions to provide necessary nutrients to the roots. One of the simplest systems to create is a basic wick.
2. To create a wick system, find containers that can fit inside each other (although you can create a single example to observe, multiple containers would be preferable).
3. Fill the top container with a light-weight, sterile growing material. The material that a plant lives in or on is called its **medium** or **substrate**. Some of the more popular choices for hydroponic systems include **perlite** (a lightweight expanded mica), a lightweight pebble-like **aggregate**, and **rockwool** (an inorganic, spongy, fibrous substance that holds large amounts of water and air). These materials provide passages among the particles or fibers where air and water can circulate. You can find these at some garden centers or through specialty hydroponic retailers.
4. Fill the bottom container with a nutrient solution. Hydroponic gardeners provide plant roots with a nutrient solution containing an appropriate balance of necessary nutrients – a "super nutrient soup" of sorts. The easiest way to supply nutrients is to purchase prepared hydroponic nutrients in dried or liquid form. Most are concentrated and must be mixed with water. When mixing nutrient solutions, always dilute them to the concentration recommended by the manufacturer.

5. Obtain small transplants to grow. Lettuce is a good choice because it is adapted to lower light levels and is also a good example of something astronauts may want to grow in space. Carefully remove the existing soil from your small plants and then plant in the top container. As you plant, you will also carefully insert a cotton or nylon wick among the roots that will then exit the container through a hole in the bottom. This wick will be used to move the nutrient solution up to the plant roots.
6. After planting your hydroponic containers, also plant a few containers of lettuce in similarly sized containers using traditional potting soil mix. Weigh all of your plants and record your findings. What are the differences in weight? Finally, place them in a sunny window or under grow lights.
7. As your plants grow in the hydroponic units, keep the nutrient solution level constant by adding water as it evaporates and is transpired, and change the solution every week or two. Try to keep the nutrient solution pH between 5.8 and 6.5 and the temperature at about 70 degrees F. Keep track of how much water is used.
8. As you water your traditional containers, also try to keep track of how much water is used.
9. Track observations daily in a journal. Describe and measure plant growth.
10. At the end of a few weeks, chart your findings. Create graphs to compare plant growth and water usage.

Making Connections:

Ask students the following questions:

- How did your hydroponic setup(s) meet different plant needs? Were there some needs that were not well met? What did you observe to make you believe that?
- If you compared plants grown with and without soils, did you observe any differences? What were they? What do you think caused them?
- Can you think of any purposes of soil that are not fulfilled by hydroponics?
- Which method used water most efficiently? Which method do you think would be better for plants grown in space?
- Would you rather raise a garden hydroponically, or with soil? Why?

Branching Out:

English – Further connect your experiences with those of real astronauts. You can read the space chronicles of International Space Station Science Officer Don Pettit describing his efforts to grow plants in space at *http://spaceflight.nasa.gov/station/crew/exp6/spacechronicles13.html*. Use the following questions to lead a discussion about his experience:

- What were some of the challenges he faced in trying to start his seeds?
- What did he use to start his seeds? Why did he think it would work?
- What did he discover when his seeds did not immediately sprout? What did he do to overcome this new challenge?
- Why did his first batch of seedlings die? What did he change on the second batch of seeds?
- Ultimately, why did his second batch of seeds die? What could he have done to help them live longer?

Science and Art – Ask students to design a space garden of their own that will provide the basic elements plants need. As they share their designs with their classmates, have them describe how it fulfills the plants' basic needs.

Science – Download The Plants in Space Class Action. The lessons in Plants in Space were developed by The National Gardening Association in cooperation with educators at NASA are an extension of the information provided in this lesson.