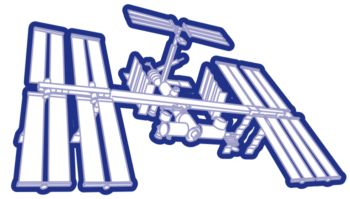
Educational Product	
Educators	Grades 5-12

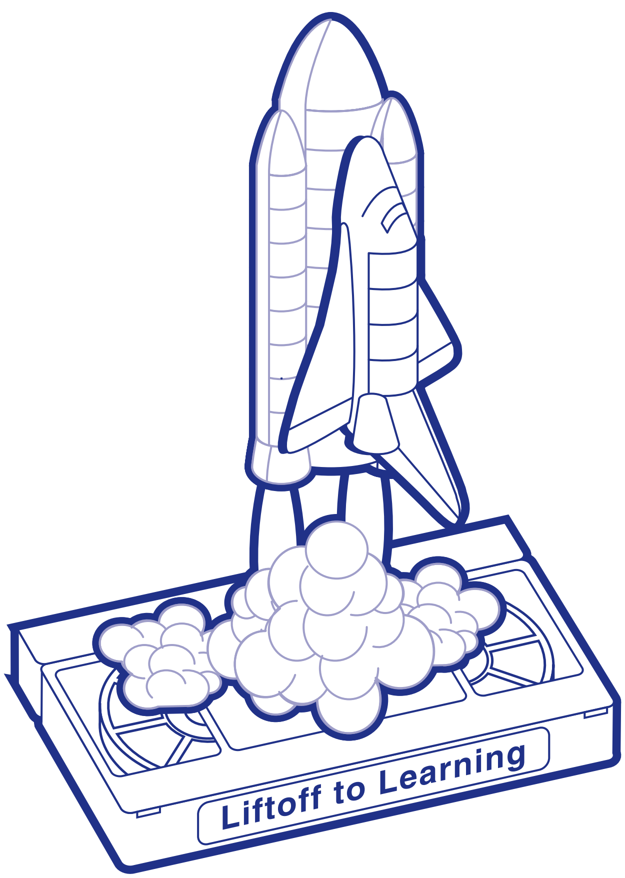
National Aeronautics and
Space Administration

Liftoff to Learning



Plants In Space

A Videotape for Biology and Life Science



Video Resource Guide

EV-1998-12-017-HQ

Video Synopsis

Title: Plants In Space

Length: 12:15

Subjects:
The video illustrates some of the basic plant growth tropisms and the effects of the microgravity environment of Earth orbit on plant growth.

Description:
Students at an elementary school participate in an experiment on plant growth with Space Shuttle astronauts. Identical seed growth pouches are planted with corn and soybean seeds. Some of the seeds are germinated on Earth and others on the Space Shuttle in Earth orbit. Rather than drawing conclusions on the effects of microgravity on plant growth, viewers are invited to participate in the experiment by growing seeds on Earth as control experiments. This video resource guide provides data on the experimental plants grown in space that can be compared with the control plants. Viewers are invited to draw their own conclusions.

Science Standards:
Unifying Concepts and Processes
- Change, constancy and measurement

Science as Inquiry
- Abilities necessary to do scientific inquiry

Life Science
- Regulation and behavior
- Structure and function in living systems

Mathematics Standards:
Measurement

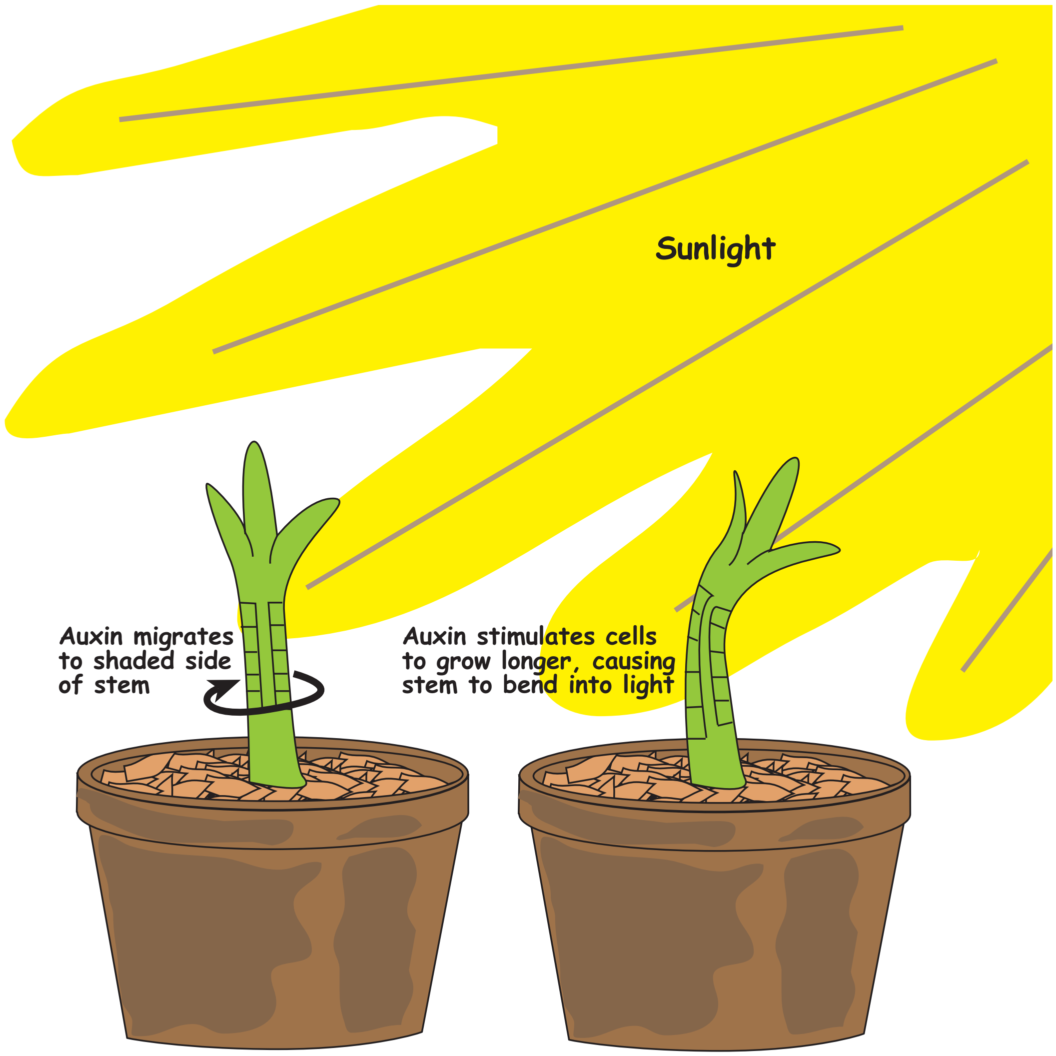
Background

Space scientists are very interested in the ability of plants to grow onboard orbiting spacecraft. Plants are being considered as a possible source of food and as an air purifier for long space voyages. In orbit, plants are exposed to an environment in which gravity's effects are greatly diminished (microgravity). Normally, plants sense gravity and respond to this stimulus by sending roots downward into the soil and shoots upward towards the light. This behavior is called a tropism. In other words, tropisms are a plant's response to stimuli. Because this specific response relates to gravity, this tropism is referred to as gravitropism.

The mechanism in plants that causes them to respond to gravity and other environmental factors, such as light, is hormone-based. Auxin (common name for indoleacetic acid) promotes or retards growth of plant cells depending upon where they are located in the plant. In stem growth, for example, auxin stimulates the elongation of young cells. If the Sun is directly overhead, all sides of the plant's stem receives the same amount of light. However, if one side of the plant is shaded, auxin will move away from the light and concentrate in the stem on the darker side of the plant. This will cause cells to elongate and bend the plant towards the light (phototropism). If the plant is tipped over, the side of the stem near the ground is shaded more and auxin stimulates growth there, causing the plant to bend upward. The upward bending is also due to gravity's effects. If the plant is tipped over in darkness, it will still bend upward (gravitropism).

In root cells, auxin inhibits growth. Auxin causes roots to grow away from light and toward the gravity force. If a root is exposed to light, auxin will inhibit the growth of the cells along the bottom edge of the root, causing the root to turn downward. Beneath the soil, auxin concentrates on the lower sides of the roots. A root that starts growing horizontally or upward will be turned into the direction of the gravity force by auxin.

Root growth is also strongly affected by the presence of water (hydrotropism). Home



Terms

Gravitropism (also called geotropism) - A plant's growth response to gravity.

Hydrotropism - A plant's growth response to water.

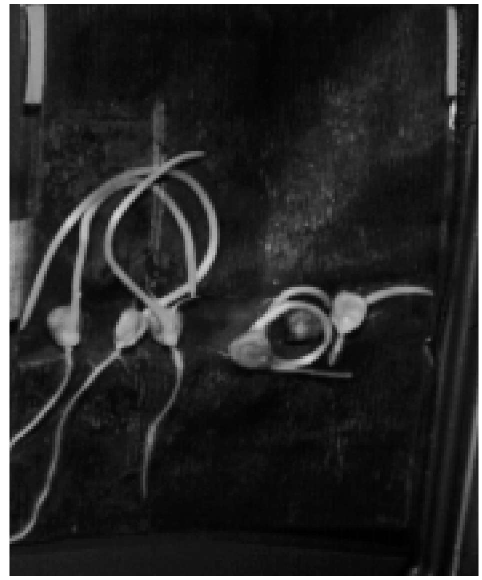
Microgravity - An environment, created by falling, in which gravity's effects are greatly reduced.

Phototropism - A plant's growth response to light.

Tropism - Response of an organism to an environmental stimulus.

owners sometimes discover they have broken sewer lines when tree roots grow to the water source and block the lines.

To learn more about plant growth in space, astronauts on the STS-91 Space Shuttle mission carried plastic seed growth pouches containing corn and soybean seeds. Upon arrival in orbit, the seed pouches were given water to cause the seeds to germinate. Half of the pouches were attached to the walls of the middeck cabin and exposed to the normal fluorescent work lights present there. The other half of the pouches were placed inside lockers in darkness. In addition to the seeds, each pouch contained two layers of brown paper towels to equally distribute the water added to the pouches. Thus, the experiment examined phototropism. Gravitropism and hydrotropism effects were eliminated. Near the end of the mission, the pouches were photographed to show the extent of stem and root growth.



STS-91 Corn Seeds Grown in Darkness

In order to analyze the results of the flight experiment, students are invited to create a control experiment. Since the corn seeds exhibited the most growth during the flight experiment, the student control experiment will concentrate on corn. Students will place corn seeds inside plastic pouches and germinate them with water. Some of the pouches will be placed in darkness and others exposed to light. Students will graph the stem and root growth daily for 10 days. At the end of the experiment, students will compare the growth of their seeds with the seeds on the Space Shuttle. To simplify the comparison of the control and the space plants, the growth of the space corn has been sketched to make details more apparent.

STS-91 Corn Seeds Grown in Light

Classroom Activities

Plants In Microgravity - Control Experiment

Materials:
Plastic zipper food bags (quart size)
Brown paper towels
Corn seeds (6 per pouch)
Gummed paper dots (1 per pouch)
10 cc syringe
10 cm long piece of aquarium hose
Distilled Water
Chlorine bleach
Eye protection
Wash pan
Strainer
Sink
Marker pen
Experiment Graph Sheets (6 per experiment pouch)
Shuttle seed growth diagram
Masking tape
Tweezers

Objectives:
To grow corn plants in growth pouches as the control group in an experiment on plant growth in microgravity.

To analyze any differences that occur between Earth-grown and space-grown corn plants.

Safety:
Be sure students wear eye protection when handling the chlorine bleach.

Seed Handling:
Students should wash their hands in soap and water or wear gloves and use the tweezers for handling the seeds. Hand contact with the seeds will contaminate the seeds with mold spores.

Procedure:
1. Prepare the seed pouches by cutting and inserting two layers of brown paper towels into the pouches. Punch a small hole through the back plastic of the pouch near the top.
2. Prepare the seeds by sterilizing their surfaces. Immerse them in a 10% chlorine bleach solution for 5 minutes. This will kill mold spores that may be clinging to the outside of the seeds. Rinse the seeds in cold water for 5 minutes.
3. Using the tweezers, slip six corn seeds inside the pouch and space them equally across the middle of the pouch in a line that will be horizontal when the pouches are stood up. Give each seed a number along the bottom of the pouch with the marker pen.
4. Seal the pouch and inject 10 cc of distilled water through the hole in the back of the pouch. Use a syringe with a small amount of aquarium hose attached to the nozzle end to insert the measured water amount.
5. Seal the hole by covering it with a gummed paper dot.
6. Tape the seed pouch to the inside wall of a closet or cabinet (for dark seeds) or to the wall (for light seeds). Stretch the plastic to keep the pouch from bulging. The seeds will probably have slipped their positions inside the pouches. Return the seeds to their horizontal row by kneading the pouch surface.
7. Measure the length of the root and stems daily. Make sure the students measure just the primary root and not the length of the secondary roots as well. Plot the results on the graph. Use one graph for each seed.

Discussion:
Although this experiment involves experimental and control groups, the experiment, as set up here, has certain problems that keeps it from being research quality. First, the corn seeds may not be identical and, unless the identical pouch is used, the pouch is another variable. Germination temperatures are likely to be different and the intensity of the lighting for the group exposed to light on the Space Shuttle will be different as well. Nevertheless, the experiment can yield interesting qualitative data on the growth of corn in microgravity. Students will notice variations in the directions of root and stem growth. Students will also gain practice in conducting experiments, collecting, and graphing data. (Due to time constraints during the mission, the Space Shuttle astronauts were not able to graph the growth.) Have students compare the seed growth in their pouches on the last day of the experiment.

Extension:
- Ask students to come up with ideas for apparatus that can be used to grow plants in space. Knowing that roots and stems may grow in odd directions, discuss strategies for using other plant tropisms (photo and hydro) for encourating plants to grow in desired directions.
- What plants might be good for space flight? (fast growing, high yield of food, high nutrition value, etc.)

Supplier Note:
The CGY Seed Growth Pouch used on the Space Shuttle was manufactured by
Mega International
3208 W. Lake Street, #22
Minneapolis, MN 55416

Experimenter Names:

____

____

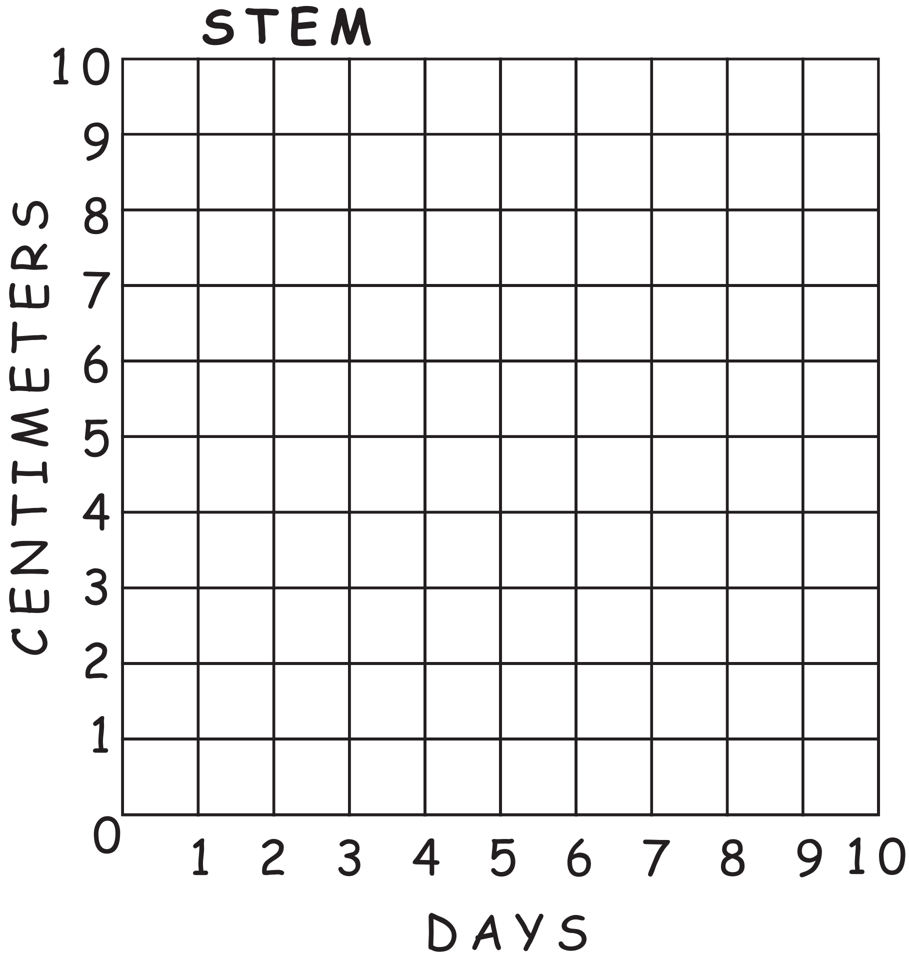
____

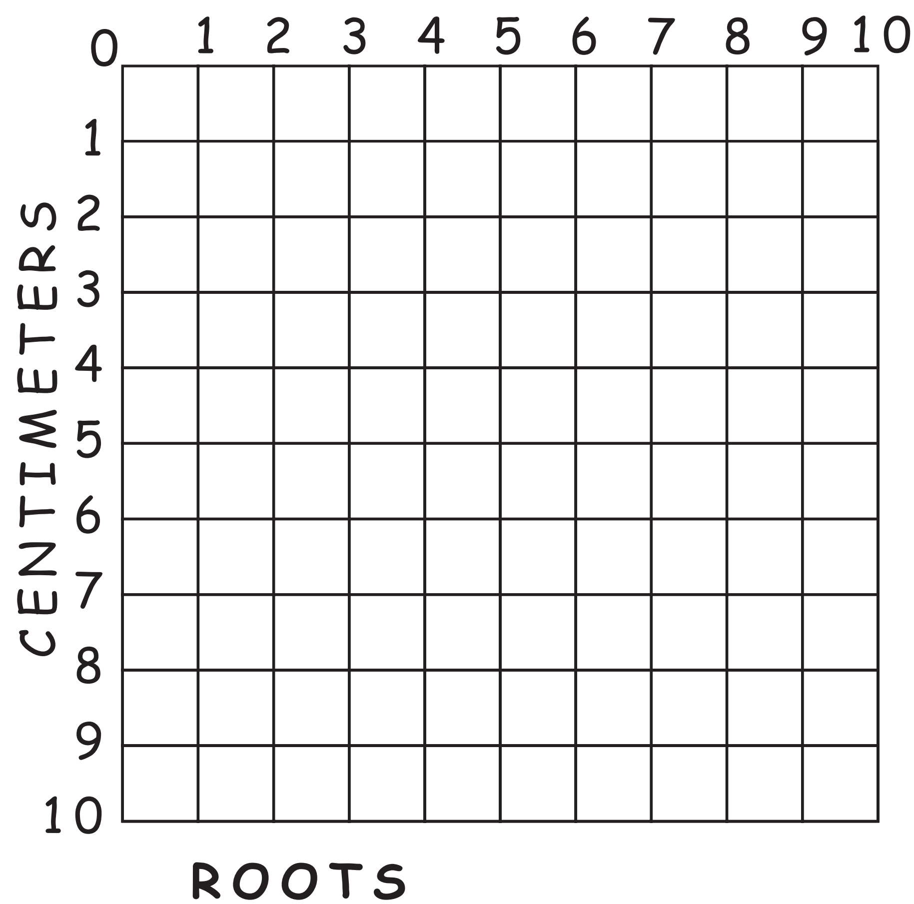
Seed Number

____

Date you started the experiment.

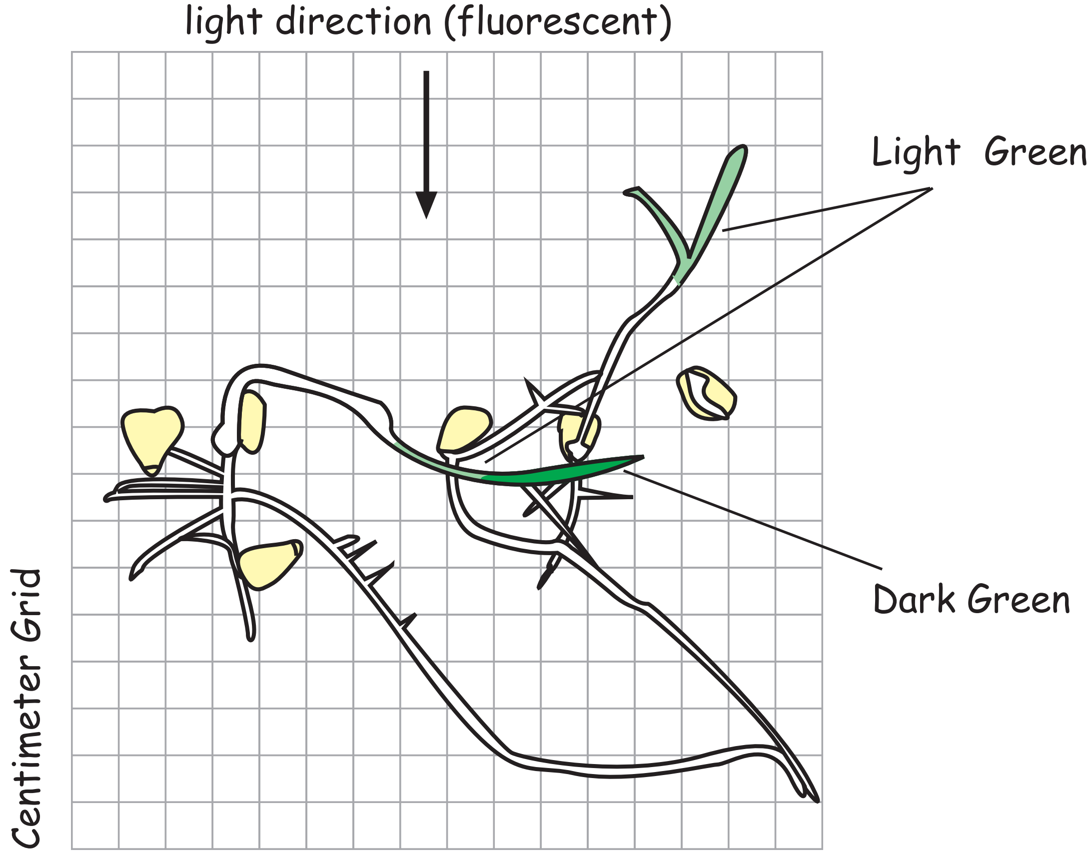
____



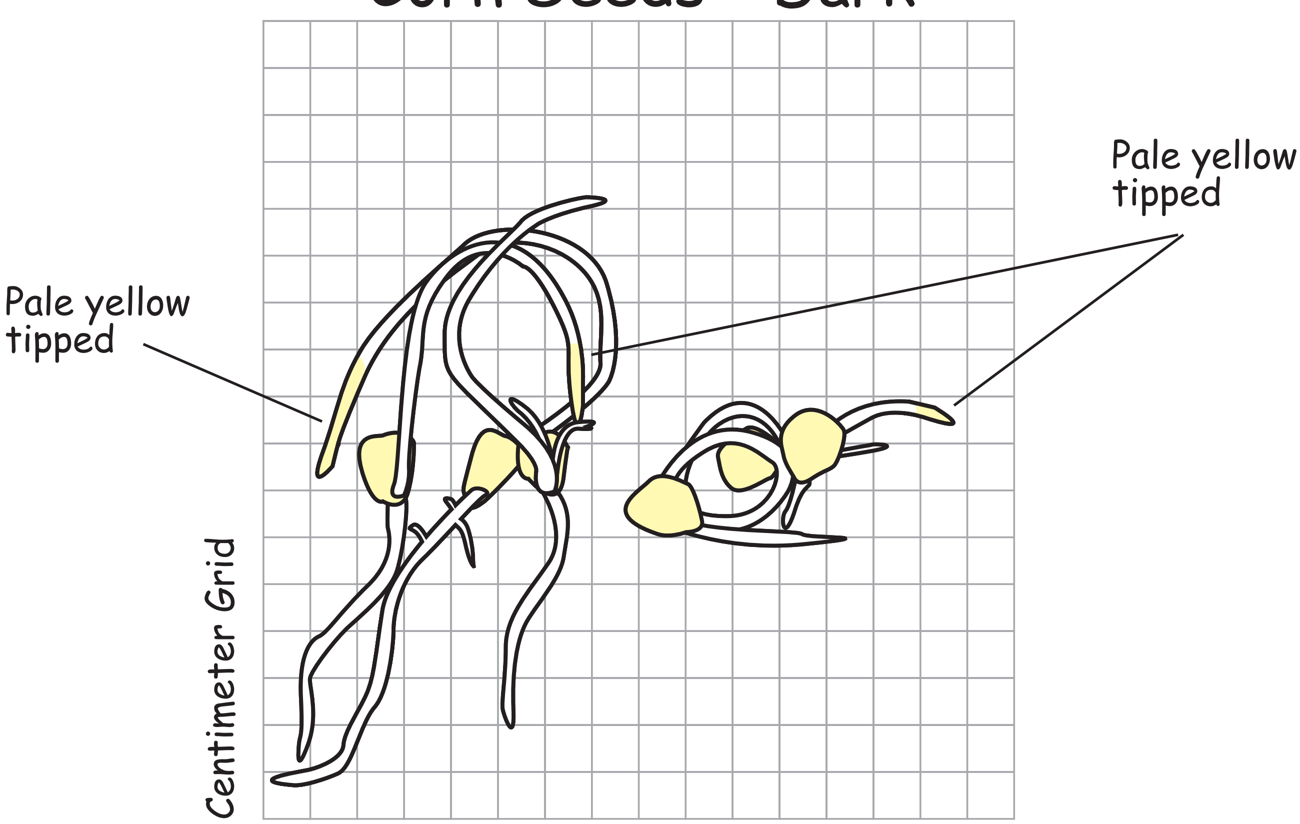


**Write your observations on the back of this paper - color, number of leaves, straight or curved stem or root, etc.
Be sure to date your observations.**

Corn Seeds - Light



Corn Seeds - Dark



References

NASA ON-LINE RESOURCES FOR EDUCATORS

NASA On-line Resources for Educators provide current educational information and instructional resource materials to teachers, faculty, and students. A wide range of information is available, including science, mathematics, engineering, and technology education lesson plans, historical information related to the aeronautics and space program, current status reports on NASA projects, news releases, information on NASA educational programs, useful software and graphics files. Educators and students can also use NASA resources as learning tools to explore the Internet, access information about educational grants, interact with other schools, and participate in on-line interactive projects with NASA scientists, engineers, and other team members to experience the excitement of real NASA projects.

Access these resources through the NASA Education Home Page: ***http://education.nasa.gov***

Other web sites of interest:

http://www.jsc.nasa.gov
http://station.nasa.gov/core.html
http://www.osf.hq.nasa.gov/heds
http://atlas.ksc.nasa.gov/celss/INTRO.HTM

STS-91 Crew Biographies

Commander Charles J. Precourt (Colonel, USAF)
Charles Precourt was born in Waltham, Massachusetts, and grew up in Hudson, Massachusetts. He received a B.S. degree in aeronautical engineering from the USAF Academy, an M.S. degree in engineering management from Golden Gate University, and an M.A. degree in national security affairs and strategic studies from the U.S. Naval War College. He also studied as an exchange student at the French Air Force Academy. Precourt flew the F-15 while based at Bitburg Air Base in Germany. As a test pilot at Edwards Air Force Base, California, Precourt flew the F-15E, F-4, A-7, and A-37 aircraft. His flight experience includes more than 6,500 hours in over 50 types of civil and military aircraft. Precourt was selected as an astronaut in1990 and flew as a mission specialist on STS-55 in 1993 and as a pilot aboard STS-71 (the first Space Shuttle mission to dock with the Russian Space Station Mir and exchange crews) in 1995. As commander of STS-84, Precourt was in charge of the sixth Shuttle mission scheduled to rendezvous and dock with Mir. At the conslusion of STS-91 he has logged more than 39 days in space.

Pilot Dominic L. Pudwill Gorie (Commander, USN)
Dominic Gorie was born in Lake Charles, Louisiana. He received a B.S. degree in ocean engineering from the U.S. Naval Academy and an M.S. degree in aviation systems from the University of Tennessee. He was designated a Naval Aviator and flew the A-7E Corsair with Attack Squadron 46 aboard the USS America. He transitioned to Strike Fighter Squadron 132 and flew the F/A-18 Hornet aboard the USS Coral Sea. He subsequently attended the U.S. Naval Test Pilot School and served as a test pilot at the Naval Air Test Center. He was assigned to Strike Fighter Squadron 87, flying the F/A-18 aboard the USS Roosevelt and participated in Operation Desert Storm, flying 38 combat missions. He then served with the U.S. Space Command in Colorado Springs for two years. Gorie was en route to his command tour of an F/A-18 squadron when he was selected as an astronaut candidate in 1994. He has served as a spacecraft communicator (capcom) in Mission Control for numerous Space Shuttle flights. Gorie has accrued over 3,800 hours in more than 30 aircraft and has over 600 carrier landings. STS-91 was his first Space Shuttle flight.

Mission Specialist Franklin R. Chang-Diaz, Ph.D.
Born in San Jose, Costa Rica, Franklin R. Chang-Diaz received a B.S. degree in mechanical engineering from the University of Connecticut and a doctorate in applied plasma physics from the Massachusetts Institute of Technology (MIT). He has been developing a new concept in rocket propulsion based on high-temperature plasma. As a Visiting Scientist with the MIT Plasma Fusion Center, he led the plasma propulsion program there from1981-1993 to develop this technology for future human missions to Mars. In 1994, he was appointed Director of the Advanced Space Propulsion Laboratory at the Johnson Space Center where he continues his research on plasma rockets. Dr. Chang-Diaz is also an adjunct professor of physics at the University of Houston. He has logged over 1,033 hours on five Space Shuttle flights. This was his sixth mission into space.

Mission Specialist Janet Lynn Kavandi, Ph.D.
Dr. Kavandi was born in Springfield, Missouri. Valedictorian of her high school class, she received a B.S. degree in chemistry from Missouri Southern State College, Joplin, and an M.S degree in chemistry from the University of Missouri, Rolla. She later earned a Ph.D. in analytical chemistry from the University of Washington, Seattle. After she received the M.S. degree, Dr. Kavandi accepted a position at Eagle-Picher Industries in Joplin, Missouri, as an engineer in new battery development for defense applications. Later, she became an engineer in the Power Systems

Technology Department of the Boeing Aerospace Company. While at Boeing, Kavandi supported numerous programs and proposals, including Space Station, Lunar and Mars Bases, the Inertial Upper Stage (IUS), NASA Get-Away Specials, Air Launched Cruise Missile, Short Range Attack Missile 11, Sea Lance, Minuteman, and Peacekeeper. While working for Boeing, she accepted a graduate school appointment at the University of Washington where she began working toward her doctorate in analytical chemistry. Her doctoral thesis focused on the development of a pressure-indicating paint used on aerodynamic models in wind tunnels to produce continuous real-time surface pressure measurements. Her work has resulted in two patents to date. She was selected as an astronaut in 1994 and has worked in the payload integration area for the International Space Station. STS-91 was Dr. Kavandi's first Space Shuttle mission.

Mission Specialist Wendy B. Lawrence (Commander, USN)
Wendy Lawrence was born in Jacksonville, Florida. She earned a B.S. degree in ocean engineering from the U.S. Naval Academy and an M.S. in ocean engineering from the Massachusetts Institute of Technology (MIT) and the Woods Hole Oceanographic Institution. Lawrence was a distinguished flight school graduate and was designated a Naval Aviator in 1982. She has logged more than 1,500 hours of flight time in 6 types of helicopters and has made more than 800 shipboard landings. After graduating from MIT, Lawrence served as officer-in-charge of the Helicopter Anti-Submarine Squadron Light THIRTY Detachment Alfa. Later, she was assigned to the U.S. Naval Academy as a physics instructor and the novice women's crew coach. Lawrence was selected to be an astronaut in 1992. She flew on STS-67, the second flight of the ASTRO observatory and aboard STS-86, the seventh mission to rendezvous and dock with the Russian Space Station Mir. With the conclusion of STS-91, she has logged more than 38 days in space.

Mission Specialist, Russian Cosmonaut Valery Victorovltch Ryumln
Valery Ryumln was born in the city of Komsomolsk-on-Amur in the Russian Far East. In 1958 he graduated from the Kaliningrad Mechanical Engineering Technical College with a specialty in Cold Working of Metal. In 1966, he graduated from the Department of Electronics and Computing Technology of the Moscow Forestry Engineering Institute with a specialty in Spacecraft Control Systems. From 1958 to 1961, Ryumin served in the army as a tank commander. From 1966 to the present, he has been employed at the Rocket Space Corporation Energia, holding the positions of: Ground Electrical Test Engineer, Deputy Lead Designer for Orbital Stations, Department Head, and Deputy General Designer for Testing. He helped develop and prepare all orbital stations, beginning with Salyut-1. In 1973, he joined the RSC Energia cosmonaut corps. A veteran of three space flights, Ryumin has logged a total of 362 days in space. In 1977, he spent 2 days aboard Soyuz-25; in 1979, he spent 175 days aboard Soyuz vehicles and the Salyut-6 Space Station; and in 1980, he spent 185 days aboard Soyuz vehicles and the Salyut-6 Space Station. From 1981 to 1989, Ryumin was flight director for the Salyut-7 Space Station and the Mir Space Station. Since 1992, he has been the Director of the Russian portion of the Shuttle-Mir and NASA-Mir Program. In January 1998, NASA announced Ryumin's selection to the crew of STS-91, the final scheduled Shuttle-Mir docking mission, concluding the joint U.S.-Russian Phase I Program. STS-91 was his first Space Shuttle flight.

Mission Specialist, NASA-Mir 7 Andrew S. W. Thomas, Ph.D.
Dr. Andrew Thomas was born in Adelaide, South Australia. He received a B.E. degree in mechanical engineering with First Class Honors and a Ph.D. in mechanical engineering from the University of Adelaide, South Australia. He then joined the Lockheed Aeronautical Systems Company, Marietta, Georgia, as a research scientist and was responsible for experimental investigations into the control of fluid dynamic instabilities and their consequences to aircraft drag. He also served as head of the Advanced Flight Sciences Department and manager of the research laboratory, the wind tunnels, and the test facilities used in studies of various problems in advanced aerodynamics and aircraft flight tests. Dr. Thomas was later appointed manager of Lockheed's Flight Sciences Division and directed the technical efforts in vehicle aerodynamics, flight controls, and propulsion systems that support the company's fleet of production aircraft. This organization also provided technical and design support to the advanced aerospace vehicle development programs sponsored within the company by the United States Air Force and NASA. In 1989, he joined the Jet Propulsion Laboratory (JPL) and was appointed leader of the JPL program for microgravity materials processing in space. Dr. Thomas was selected to be an astronaut by NASA in March 1992. He previously flew on STS-77 and STS-89. Thomas returned with the STS-91 crew after spending approximately 120 days aboard the Mir Space Station, the final scheduled Shuttle-Mir docking mission, concluding the joint U.S.-Russian Phase I Program.

Liftoff To Learning
Plants In Space

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Video Resource Guide

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