



Germination: Launching the Seed

Concepts

Germination is the awakening of a seed (embryo) from a resting state. It involves the harnessing of energy stored within the seed and is activated by components in the environment.

In the metaphor of a space shuttle mission, germination, like launch, involves the bringing together of essential chemicals, hydrogen and oxygen, to generate energy that will be directed toward expanding and propelling the two growing points of the germinating seed outward (upward and downward if guided properly).

Questions

- What are the main components of the environment necessary for germination?
- How does the germinating seed go about harnessing its stored energy and using the environment?
- How does a germinating seed 'know' which way to grow?
- What developmental events enable the emerging plant to shift its dependency from stored energy to the energy from light?

Background

Germination is the beginning of growth of a plant from a previously dormant seed which contains the embryo. Germination begins when the seed takes up water (*imbibition*) and the seed coat cracks.

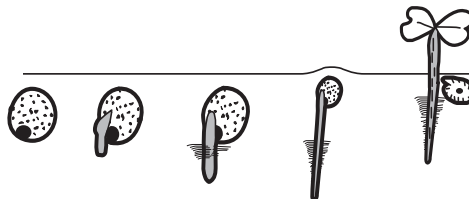
An embryonic root (*radicle*) emerges from the seed and develops root hairs that bring in water and nutrients. In Fast Plants, an embryonic stem (*hypocotyl*) elongates, pushing the seed leaves (*cotyledons*) upwards through the soil. As they emerge from the soil the cotyledons expand. The cotyledons serve as an energy source until true leaves form. These events happen on Days 1, 2 and 3 of the Fast Plants life cycle (see Figure 1). For germination to take place, water and oxygen are needed and the temperature must be suitable.

With germination, water is the "on" switch. Water taken up by the dry seed hydrates the cytoplasm, activating enzymes, solubilizing substrates, loosening the structural fabric of walls and providing pressure that enlarges the cells, resulting in expansion and growth. Oxygen, another essential ingredient, combines with hydrogen from the stored oil reserves in the embryonic seed leaves and fuels the metabolic combustion that powers life processes. Rapid development of the fine root hair cells vastly increases the surface area of the root, facilitating the uptake of water that drives the elongation of the hypocotyl, which pushes the seed leaves and shoot meristem upward through the soil.

**Fueled
by a million
man-made
wings of fire--
the rocket tore a tunnel
through the sky--
and everybody cheered.**



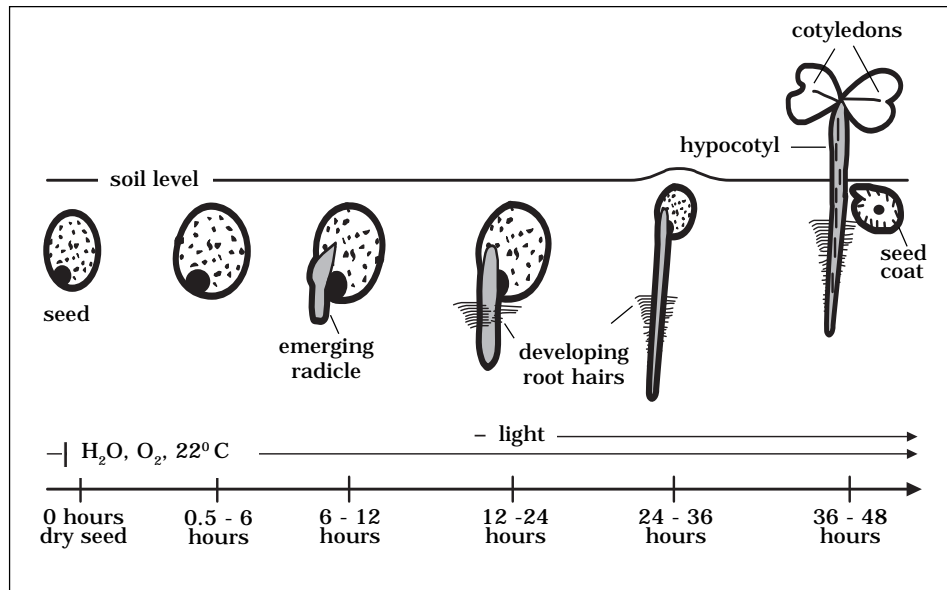
**Fueled
....[from within]...
the seedling
urged its way
through the thicknesses of black--
and as it pierced
the heavy ceiling of the soil--
and launched itself
up into outer space--
no one even clapped.**



edited from a poem by Marcie Hans

On Earth, orientation during germination is provided by gravity. Roots respond positively to gravity by growing downward (*positive gravitropism*), while shoots respond negatively by growing upward (*negative gravitropism*). Prior to emerging from the soil into the light, the germinating brassica seedling is dependent on the energy reserves stored in the seed leaves. Seeds of other plant species may also store carbohydrates, starch (cereals) or protein (legumes, beans).

Figure 1: Germination in Fast Plants



Upon emergence from the soil and triggered by the light, the cotyledons expand, casting off the protective seed coat, turn green and become photosynthetically active. At this point the "plant" becomes independent of the stored reserves and dependent on the energy of light. Launch has been successful! The solar panels (cotyledons) have been deployed. The future success of the mission depends on keeping the panels oriented and operational to gather light energy which is converted through photosynthesis to chemical energy for growth, flowering and reproduction.

The following activity will provide students with insight into the various stages of germination and give them an introduction to the phenomena associated with orientation. Remember, one of the big questions about the microgravity environment is: how will plants know which way to grow?



Launching the Seed

Introduction

In the WFPID *Getting Acquainted with a Seed*, students find that on brassica (Fast Plants) seeds the tip of the embryonic root points down toward the micropyle, near a darkened circular area on the seed coat associated with the attachment of the seed to the maternal ovary by way of the funiculus. Follow the steps below to begin to explore the interaction of germination and orientation.

Question: For a brassica or other seed, which way is down? Or up?

Sample Hypothesis: The dark spot near the micropyle is down – brown is down.

Sample Null Hypothesis: Brown is up.

Design:

- Germinate seeds oriented in different directions. Observe and record initial and later direction of root emergence from seed. Alter orientation of seedlings, predict, observe and record responses.
- Observations are recorded on the "Launching the Seed Student Sketch Sheet."

- **Design Tip:** You may want to begin this activity on a Monday, so that your germination will occur during the week when students can make observations. Alternatively, students may set it up and observe it at home.

Time Frame

Students will be able to construct their seed germinator and place their seeds within one 50 minute class period. This activity is designed for the student to observe their germinators over a two to three day period. Data are collected as drawings and a written discussion. Time for observations should be five to ten minutes on each of three consecutive days.

Learning Objectives

In participating in this activity students will:

- determine whether their understanding of seed anatomy from WFPID *Getting Acquainted with a Seed* is correct and their hypothesis regarding seed orientation is verified, namely that the micropyle is the down orientation in brassica seeds; and
- understand that plant roots reorient in the direction of their growth to conform with the direction of the gravitational force.

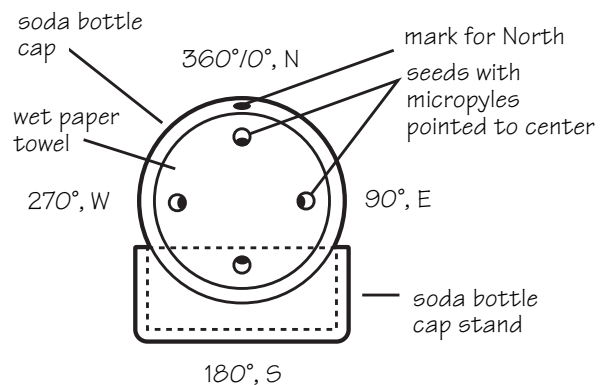
Materials

- two soda bottle caps (film can lids will also work)
- kitchen plastic wrap
- paper toweling
- four Fast Plants seeds
- forceps for handling seed
- hand lens
- elastic band

Procedure

1. Cut two layers of paper towel into circles that will fit into the bottom of a soda bottle cap.
2. Place the towel in the cap and moisten it with water. Pour off any excess water.
3. Orient the four seeds in north-south-east-west positions on the moist towel surface, making sure that the brown micropyle area (spot) is pointing toward the center of the cap (Figure 2).
4. Make a mark on the bottle cap that indicates the direction of north, or up.
5. Cover the open cap with plastic wrap and secure the wrap with an elastic band. Trim off excess wrap with scissors.
6. Position the "bottle cap seed germinator" so the seeds are in a vertical orientation by standing it in a second bottle cap (Figure 3).
7. Make a drawing of the seeds in the bottle cap germinator, including the orientation of the brown micropylar area toward the center of the circle. Use the "Circle 1" on the Launching the Seed Student Sketch Sheet.

Figure 2: Front view of bottle cap seed germinator.



8. If students carry their bottle cap seed germinator home with them, they can **observe it every few hours**. Be sure to keep it in the vertical position with the proper north-south-east-west orientation.

9. When the roots begin to emerge, record the direction of the emerging root from each seed with a second drawing on the Sketch Sheet (Circle 2). You may wish to use a hand lens.

10. Continue to observe the germinating seeds being sure that the paper towel is kept moist. Note the appearance of the fine, fuzzy root hairs and the extension of the hypocotyl.

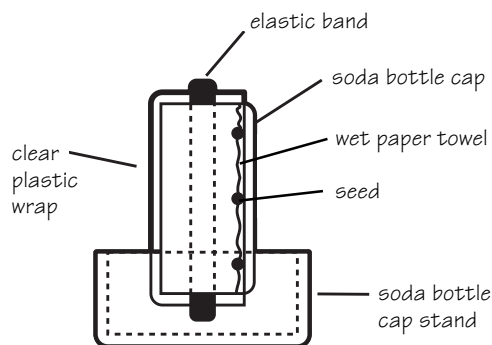
11. **After 24 to 48 hours**, make a third drawing depicting the direction of the roots and hypocotyl and illustrating the root hairs, cotyledons and seed coat (Circle 3).

12. Then reorient your bottle cap seed germinator in some way that will give you more information on seed orientation. Make another drawing that predicts how the seedlings will look after 12 or 24 hours in this new orientation (Circle 4). Observe them from time to time – do you notice anything happening?

14. **Twelve or 24 hours** after reorientation, draw the seedlings on the Sketch Sheet (Circle 5). Has anything changed? Compare the outcome of the orientation with what you predicted in your last drawing.

15. Have students write about what they have learned on the Sketch Sheet.

Figure 3: Side view of bottle cap seed germinator.

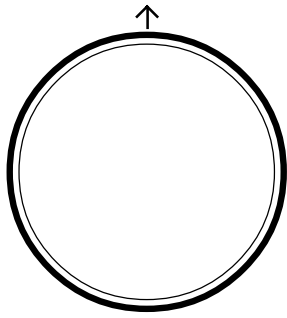


Concluding Activities and Questions

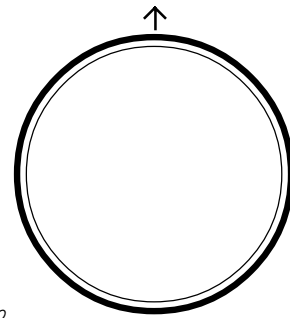
In this activity students will have observed the effects of the Earth's gravity in reorienting the direction of roots in the direction of the gravitational force. They will also have observed that shoots orient against the direction of the gravitational force, bending and growing upward. This should raise a discussion around the questions:

- In microgravity which direction will roots and shoots grow?
- Is there a guiding force for root growth in the absence of gravity? Could you generate a hypothesis and experiment to carry this question farther? **Hint:** What would happen if you ran this experiment on a centrifuge?
- What might be the possible influence(s) of light in this experiment?

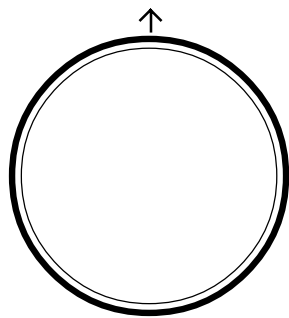
Launching the Seed Student Sketch Sheet



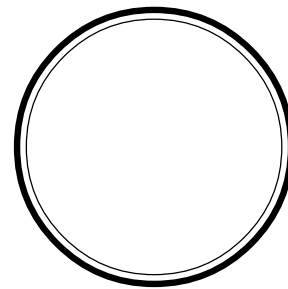
Circle 1:
Sketch and label your bottle cap seed germinator at time of placement of seeds.



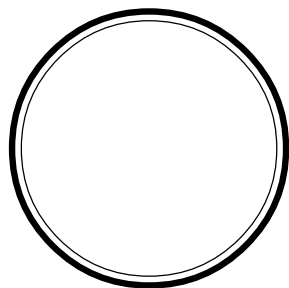
Circle 2:
Sketch and label your bottle cap seed germinator as the roots emerge from the seeds.



Circle 3:
Sketch and label your bottle cap seed germinator 24 to 48 hours after placement of seed.



Circle 4:
Sketch and label your bottle cap seed germinator with your prediction of the effects of reorientation on your seedlings.



Circle 5:
Sketch and label your bottle cap seed germinator 12 or 24 hours after reorientation to compare with sketch in Circle 4.

Write about what you have learned about germination and orientation.
