Plants Know the Way to Grow

As students study plants they are sure to notice that plants seem to "know" which way to grow. Germinating seedlings emerge above the soil and grow upward. On a windowsill plants turn toward light. Observations that downward growth of root (toward water) and upward growth of the shoot (toward light) are critical to a plant's survival lead to questions such as:

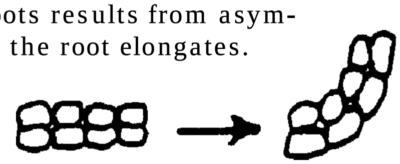
- Why do plants grow up?
- Why do plants grow toward light?
- Which response is stronger - growing up or growing toward light?
- Is the response to light related to a particular color of light?

The Fast Plants experiments in this document address these questions which have intrigued plant scientists for years. Though we aren't sure what causes these responses, the following information explores current hypotheses.

The Ups and Downs of Life

How do plants know which way is up (and which is down)? The response *(gravitropism)* seems to be mediated by the root cap and shoot tip. In roots, perception of the direction of gravity appears to depend on the settling of dense particles (organelles called *amyloplasts*) in specialized root cap cells. When the plant is turned, within minutes amyloplasts sink toward the source of gravity, to the side of the cell that is currently "down."

Curving of the roots results from asymmetric growth as the root elongates. Picture two layers of cells attached to each other. If only one layer elongates, it forces the two layers to bend. Movement will be away from the side where elongation occurs.



Elongation of plant cells is affected by a plant growth hormone called *auxin*. Auxin concentration appears to parallel amyloplast distribution leading to a gravity induced auxin gradient across the shoot or root tip. In root studies, calcium levels rise where amyloplasts accumulate. This may activate pumps in the membrane to pump calcium and auxin out of the lower side of the cells, so calcium and auxin accumulate at the lower side of the root cap.

If root and shoot cells were affected in the same way by differential auxin concentration, plants would grow in circles. Fortunately, auxin stimulates cell elongation in shoots but inhibits it in roots. The same system allows roots to bend toward the source of gravity *(positive gravitropism)* and shoots to bend away from it *(negative gravitropism)*.

An important control is lacking from experiments done so far - we cannot eliminate gravity while on Earth. Only experiments in space demonstrate plant response in the absence of gravity. Future Fast Plants experiments performed in conjunction with NASA on Space Shuttle missions may answer some of the questions about tropisms in microgravity (see Wisconsin Fast Plants *Notes*, Spring 1995 issue, Vol. 8, No. 1).

The Light Side

Negative gravitropism leads plants to grow up out of the Earth but growth of the shoot directly toward the sun is even more advantageous to a photosynthetic organism. This response (phototropism) is apparently mediated by the shoot tip and has been mostly studied in coleoptiles (the sheath around cereal grain shoots). Unequal auxin distribution also seems to be involved, with auxin apparently transported away from the lighted side toward the darker side of the shoot.

Since auxin stimulates cell elongation in shoots, this produces unequal growth on the two sides of the shoot and the shoot bends toward the light. Research has shown phototropism to be a response to blue light but the receptor is not well established. The receptor is not a phytochrome, and experiments indicate that a likely candidate is a flavoprotein.

Phototropic and gravitropic responses share several properties. A stimulus (light or gravity) leads to unequal distribution of auxin. The change in auxin distribution almost certainly results from a lateral migration of auxin rather than from differential synthesis or degradation. Root or shoot bending is due to differential cell enlargement in response to differing auxin concentrations.

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There is a lot more room for research! Experiments in this document introduce the phenomena of gravi- and phototropism. Your experimentation is limited only by your imagination - try combinations of growth in dark or light, in different colors of light, in different growth orientations, and so on.

Materials

- Fast Plants seeds (phototropism, gravitropism experiment 1) or 3- or 4-day-old Fast Plants seedlings (gravitropism experiment 2)
- 35 mm opaque film cans
- mylar plastic sheets, assorted colors
- single hole paper punch
- clear plastic tape (3/4" width)
- black plastic electrical tape
- paper toweling or blotting paper
- scissors

Make a phototropism chamber

1. Punch three holes in the film can, evenly spaced around the can about 1 cm down from the rim.
2. Tape a square of colored plastic over each hole with clear tape. Cover all holes to maintain humidity inside the chamber.
3. Place a small amount of water in the bottom of the can.
4. Place three paper towel wick strips on the inside of the can, one between each pair of colored windows. Allow the water to wick up the toweling via capillary action.
5. Place 3 seeds on each wick strip in a triangle, slightly below window level.
6. Carefully replace the lid on the can and place in under a light bank.
7. After 72 hours, open the chamber and observe which way your plants have grown.

Gravitropism - Experiment 1

1. Sow 3 seeds on a square of wet blotting paper in a windowless chamber (see Figure 1). Place the chamber horizontally and mark which side is up with a pen.

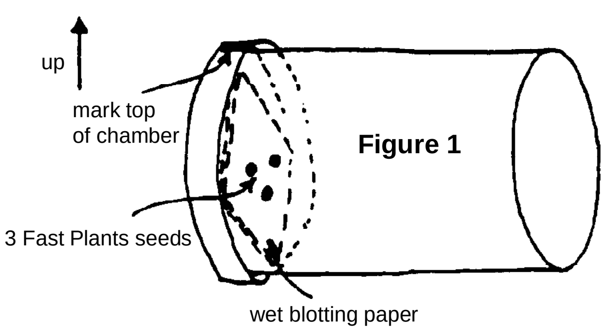


Figure 1

2. Observe 1 and 2 days later and record what you see. Replace cap tightly and return the chamber to the same horizontal position.
3. When you are done observing, seedlings may be planted in potting mix and used for further study.

Gravitropism - Experiment 2

1. Set up another windowless chamber.
2. Add just enough water to cover the bottom of the film can.
3. Wet a paper towel wick strip. Stick it to a plastic grid strip (see Hints for directions for making grid strips).
4. Put the wick and grid strip on the inside wall of the film can, with the grid strip between the wick and the side of the can. The wick should be in contact with the water in the film can.
5. Stick a seedling to the wick strip, with the cotyledons against the wick and the hypocotyl pointing out into the can (see Figure 2).

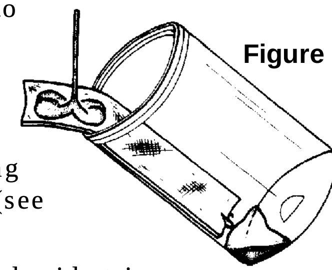


Figure 2

6. Push the wick and grid strip below the lip of the can and carefully replace the lid (see Figure 3).

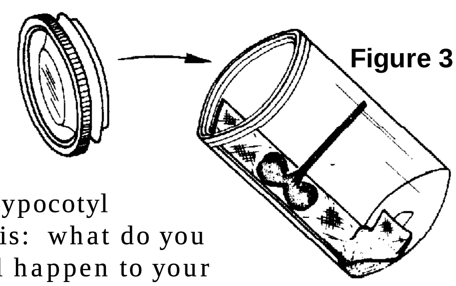


Figure 3

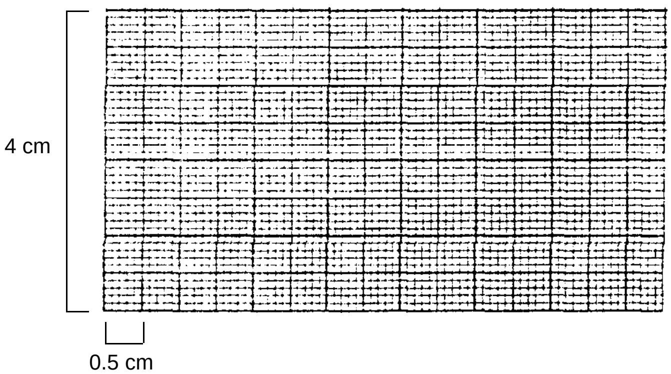
7. Make a hypocotyl hypothesis: what do you think will happen to your seedling? After 4 to 6 hours, peek!
8. What additional experiments can you design based on your observations?

Hints for making and using tropism chambers

- Cover all holes in your chambers with plastic tape to maintain the humidity.

- Making grid strips:

  - Photocopy the section of grid paper below onto a transparency sheet, or
  - Photocopy a sheet of graph paper (10 mm to the cm) onto a transparency sheet.
  - Cut strips 4 cm long by 0.5 cm wide.



Extensions

- Construct a phototropism chamber with different sized holes covered with clear plastic to explore the etiolation and the effects of light intensity and angle of incidence.

- Construct a set of chambers, with each chamber having a different color plastic over its windows to explore the effect of light color on germination and early growth stages.

- Construct a phototropism chamber and cover one or more holes with black electrical tape for all or a portion of your experiment time.

- Place a phototropism chamber on its side with the window facing down but allowing some light to enter. Will the response to light or gravity be stronger?

- Place your seedling gravitropism cans on a spinning turntable. What will be the response of the hypocotyl? What will be the effect of varying the distance from center?